Investigation the impact of maximum control point on dose calculation in Eclipse treatment planning system for lung SBRT

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Original Article

Abstract

Purpose: Choosing an appropriate parameter on the computerized treatment planning systems (TPSs) influences on the accuracy of dose calculation. Several dosimetric parameters have been studied to achieve a more accurate dose and qualitative plan. The purpose of this study was to determine the impact of maximum control point on the dose calculation on Eclipse TPSs for lung Stereotactic Body Radiation Therapy (SBRT) considering the plan quality, the computation time and the treatment file size. **Methods:** Dose distributions for the 8 lung SBRT plans with varying maximum control point of 64, 166, and 320 were calculated by Eclipse TPSs with flattening filter free (FFF) beam. The treatment dose was prescribed at 85% isodose level of 54 Gy to the planning target volume (PTV). The dosimetric impact can be evaluated from target coverage, conformity index (CI), homogeneity index (HI), and organ at risk (OAR) doses, while the computation time and the file storage space were compared with the recommended number of control point. **Results:** The use of 64 control points per subfields tended to increase the dose at PTV and OARs comparing with the 166 and 320 control point plans, while the HI and CI values were similar. The average increases of OARs doses including the spinal cord, heart, esophagus and total lung depended on the photon beam energy. The higher average control point (AVG) number leaded to increase the computation time and the file size for both 6X-FFF and 10X-FFF photon beams. The correlations between AVG and plan storage space were observed in the same ratio as the computation time. **Conclusion:** Using the minimal number of control point, the quantitative analysis in the PTV and OARs showed no clinically significant variation in dose, therefore choosing an optimal number of fixed control points leaded to balance the plan quality, the computation time and the file size.

Keywords: Control point, Stereotactic body radiation therapy, Dynamic multileaf collimator, Intensity modulated radiation therapy.

1. Introduction

Stereotactic body radiation therapy (SBRT) is an alternative treatment option for patients with localized non-small cell lung cancer. Use of intensity-modulated radiation therapy (IMRT) technique to treat lung SBRT has been shown to increase the local tumor control compared to the standard fractionation treatments.[1] The IMRT can provide the conformal dose distribution around the target volume by using the dynamic multileaf collimator (DMLC). Several doismetric planning parameters for the dose calculation in DMLC-IMRT technique have been studied to achieve a more accurate dose and qualitative plan. Huang *et al*[2] has reported the dose differences between the Anisotropic Analytical Algorithm (AAA) and ACUROS XB (AXB) in lung SBRT treatment with flattening filter free (FFF) beams. Park *et al*[3] determined the optimal grid size and angular increment for the dose calculation in lung SBRT using dynamic conformal arc therapy (DCAT). Chung *et al*[4]

found a 2 mm grid size produced a dose difference of 2.3% of prescribed dose as compared to 1.5 mm grid size in an IMRT plan.

The control point is one of the dosimetric parameters affected to the plan quality, the transfer and loading times, and file storage space, as presented in the study of Goraj *et al*[5]. It associates with the specification of a percentage of the set beam monitor units (MU) in a DMLC delivery.[6] The DMLC-IMRT treatment plans created in Eclipse treatment planning system (TPSs) can adjust the number of control point ranging from 64-320 control points for each treatment field.[7]   Theoretically, a higher number of control points results in a higher number of beam fluence.

The purpose of this study was to investigate the effect of maximum control point numbers on Eclipse TPSs for lung SBRT plan using DMLC-IMRT technique. Dose variations in both the planning target volume (PTV) and organ at risk (OAR), the computation time, and the file storage space with varying maximum control points were analyzed.

2. Methods and Materials

The 8 lung SBRT patient data were retrospectively selected to estimate the dose variation as a function of maximum control point. The computed tomography (CT) images were obtained over the lung region of patient through Brilliance Big Bore 16-slice (Philips Healthcare, Andover, MA) CT scanner with a slice thickness of 3 mm. A four-dimensional (4D) CT images acquired with the real-time position management (RPM) system were used to generate the internal target volume (ITV). Expanding a 0.5 cm margin in the axial plane and 1.0 cm margin in the longitudinal plane from the ITV was defined as the PTV.[8] An equivalent diameter of PTV for all patients was ranging from 3.7 to 6.7 cm. In this study, the OARs included the spinal cord, heart, esophagus and normal lung. The clinical characteristics of the 8 lung SBRT plans were listed in Table 1.

Treating the lung SBRT on True Beam linear accelerator (Varian Medical Systems, Palo Alto, USA) was performed with a maximum dose rate of 1400 MU / min and 2400 MU / min for 6X-FFF and 10X-FFF photon beams, respectively. Dose distributions with varying maximum control point of 64, 166, and 320 were calculated by Acuros XB (AXB) algorithm on Eclipse TPSs version 11.0.31 (Varian Medical Systems, Palo Alto, USA) with 2 mm grid sizes. The prescription of 85% isodose level of 54 Gy to the PTV was specified in this study. The isodose distributions of the SBRT plans were computed and analyzed.

The quality of each planned dose distribution can be assessed from target coverage, conformity index (CI) and homogeneity index (HI) of the PTVs and the dose

variation of the OARs. Dose homogeneity index determines the uniformity of the dose distribution within the target volume. Following the International Commission on Radiation Units and Measurements (ICRU) report number 62[9-10], the HI is given by

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \qquad (1)$$

where $D_{2\%}$, $D_{50\%}$ and $D_{98\%}$ are the target volume receiving the 2%, 50% and 98% of prescribed dose, respectively. If the HI equals to zero, the dose distribution of the PTVs is almost homogeneous.

The degree of high dose conformity around the PTV can be evaluated from dose conformity index. Following the Radiation Therapy Oncology Group (RTOG)[9-10], the CI is given by

$$CI_{RTOG} = \frac{V_{RI}}{TV} \qquad (2)$$

where V_{RI} represents the volume of reference isodose and *TV* is the target volume. If the CI equals to 1, the dose distribution is indicated to conform the PTV.

According to the King Chulalongkorn Memorial Hospital SBRT protocol, the OARs including the spinal cord, heart and esophagus were evaluated as a maximum dose point, while the total lung was analyzed at the dose to 1000 cc volume. All DMLC-IMRT plans were transferred from the Eclipse TPSs to ARIA oncology information system version 11.0.31 (Varian Medical Systems, Palo Alto, USA) and the delivery unit. Both computation time and file storage space with varying control point were also collected and compared with that for the defaulted maximum number of control point.

3. Results

The differences in the average mean dose, HI and CI of the PTV derived from a variable number of control point for both 6X-FFF and 10X-FFF photon beams were summarized in Table 2.

The 64 control point per subfields tended to increase all PTV mean doses for both 6X-FFF and 10X-FFF beams when compared to the 166 and 320 control point plans. For the 6X-FFF beam, the maximum increases of the PTV mean dose were 0.46% (26.7 ± 1.0 cGy) and 0.50% (29.1 ± 1.5 cGy) for one of the plans using the control point of 166 and 320, respectively. For the 10X-FFF beam, the maximum increases of the PTV mean dose were 0.35% (20.9 ± 3.7 cGy) and 0.37% (22.5 ± 1.9 cGy) for one of the plans using the control point of 166 and 320, respectively. Although the dose calculation using the minimal control point number leaded to increase the PTV mean dose, the HI and CI do not differed significantly among these plans.

Table 1: Characteristics of the PTV and planning parameters for the 8 lung SBRT patient data

Patient	Equivalent diameter of PTV (cm)	Energy (MV)	No of treatment fields	Tumor location
1	3.7	6X-FFF	9	Left middle lobe
2	4.2	10X-FFF	7	Right middle lobe
3	5.1	10X-FFF	9	Left middle lobe
4	5.1	10X-FFF	7	Right upper lobe
5	5.4	6X-FFF	7	Right middle lobe
6	6.1	10X-FFF	9	Left lower lobe
7	6.4	10X-FFF	9	Right upper lobe
8	6.7	6X-FFF	9	Right middle lobe

Table 2: Comparison of average mean dose, HI and CI of the PTV calculated with the 64, 166, and 320 control points for both 6X-FFF and 10X-FFF photon beams

Item	Max control point number	Average value	
		6X-FFF	10X-FFF
PTV mean dose			
	64	5903.9 ± 353.7 cGy	6062.8 ± 356.7 cGy
	166	5887.8 ± 351.6 cGy	6046.1 ± 354.7 cGy
	320	5887.1 ± 351.5 cGy	6045.5 ± 354.8 cGy
HI			
	64	0.243 (0.20 - 0.28)	0.238 (0.17 - 0.30)
	166	0.243 (0.20 - 0.28)	0.238 (0.17 - 0.30)
	320	0.243 (0.20 - 0.28)	0.238 (0.17 - 0.30)
CI			
	64	0.983 (0.93 - 1.09)	0.998 (0.92-1.06)
	166	0.977 (0.92 - 1.09)	0.992 (0.91-1.06)
	320	0.977 (0.92 - 1.09)	0.990 (0.91-1.06)

Table 3 presented the dose differences of the OARs derived from the maximum control point number of 64, 166 and 320 for both 6X-FFF and 10X-FFF photon beams. We found an effect of variable control point number on the maximum dose of heart, esophagus and spinal cord, and the dose to 1000 cc volume of total lung. The maximum dose of the OARs was mostly shown to increase overall when calculated with the 64 control point for both 6X-FFF and 10X-FFF beams. The maximum increases of the dose were 0.395% for the spinal cord, and 0.568% for the heart and total lung in the 6X-FFF beam. For the 10X-FFF beam, the maximum increasing doses were 0.206% for the total lung, 0.214% for the esophagus, 0.231% for the heart, and 0.505% for the spinal cord.

When the DMLC-IMRT plans were calculated with a variable number of control points, the calculation time and the file size were differed. Table 4 presented the time for calculation in the unit of minutes and the size of treatment plan in the unit of Kilobyte (KB) for both 6X-FFF and 10X-FFF photon beams. Comparing with the 166 control point plan, the computation time of the 64 control point plan was increased by average of 0.12 ± 0.03 and 0.43 ± 0.26 minutes for the 6X-FFF and 10X-FFF beams, respectively. Using the lowest control

point number, the storage spaces of treatment plan were reduced by average of 38.50 ± 5.61% and 47.67 ± 5.60% for the 6X-FFF and 10X-FFF beams, respectively, when compared with the 166 control point plan. The computation time and plan storage space obtained from the 166 and 320 control points do not differed significantly.

4. Discussion

In this study, we found that the maximum number of control point impacts on the plan quality, computation time and file size. At the lowest number of control point, the dose at the PTV and OARs including the spinal cord, heart, esophagus and total lung tends to increase when compared with the 166 and 320 control point plans, while the HI is similar. On average, the differences of PTV mean dose obtained from the 166 and 320 control point plans are within 0.27% and 0.29% of the 64 control point plan for both 6X-FFF and 10X-FFF beams, respectively. The average differences of OARs dose when compared with the 64 control point plan were summarized in Figure 1. We observed that the dose variations derived from the 166 and 320 control point plans do not differ significantly in the dose at the PTV and OARS.

Table 3: Comparison of the OARs dose derived from the 64, 166, and 320 control point plans for both 6X-FFF and 10X-FFF photon beams

Patient	OARs	Location	Dose (cGy)		
			64	166	320
1	Heart	Max	127.2	127.1	127.1
	Esophagus	Max	894.3	891.2	891.2
	Spinal cord	Max	358.3	358.1	358.1
	Lung	V_{1000cc}	119.9	119.7	119.7
2	Heart	Max	96.3	96.2	96.4
	Esophagus	Max	-	-	-
	Spinal cord	Max	85.3	85.2	85.2
	Lung	V_{1000cc}	35.0	35.0	35.0
3	Heart	Max	372.9	372.7	372.5
	Esophagus	Max	1654.1	1651.1	1651.2
	Spinal cord	Max	875.6	872.7	872.7
	Lung	V_{1000cc}	353.4	353.0	352.7
4	Heart	Max	48.8	48.5	48.5
	Esophagus	Max	3638.4	3646.1	3645.4
	Spinal cord	Max	1233.9	1231.3	1231.8
	Lung	V_{1000cc}	17.0	17.7	17.7
5	Heart	Max	1767.6	1757.6	1757.0
	Esophagus	Max	1691.7	1694.8	1694.1
	Spinal cord	Max	941.3	938.1	937.6
	Lung	V_{1000cc}	214.1	212.9	213.1
6	Heart	Max	4396.2	4389.2	4384.5
	Esophagus	Max	1232.7	1231.6	1231.3
	Spinal cord	Max	1507.6	1505.5	1505.5
	Lung	V_{1000cc}	82.2	82.1	82.0
7	Heart	Max	5418.3	5407.2	5405.8
	Esophagus	Max	2051.7	2049.0	2049.1
	Spinal cord	Max	2228.4	2219.0	2217.2
	Lung	V_{1000cc}	73.1	73.1	73.0
8	Heart	Max	4795.3	4791.8	4793.5
	Esophagus	Max	2417.0	2420.1	2420.8
	Spinal cord	Max	4532.3	4539.1	4527.3
	Lung	V_{1000cc}	612.8	612.6	612.1

Table 4: Comparison of the computation time and file size as a function of maximum number of control point for the 8 lung SBRT patient data

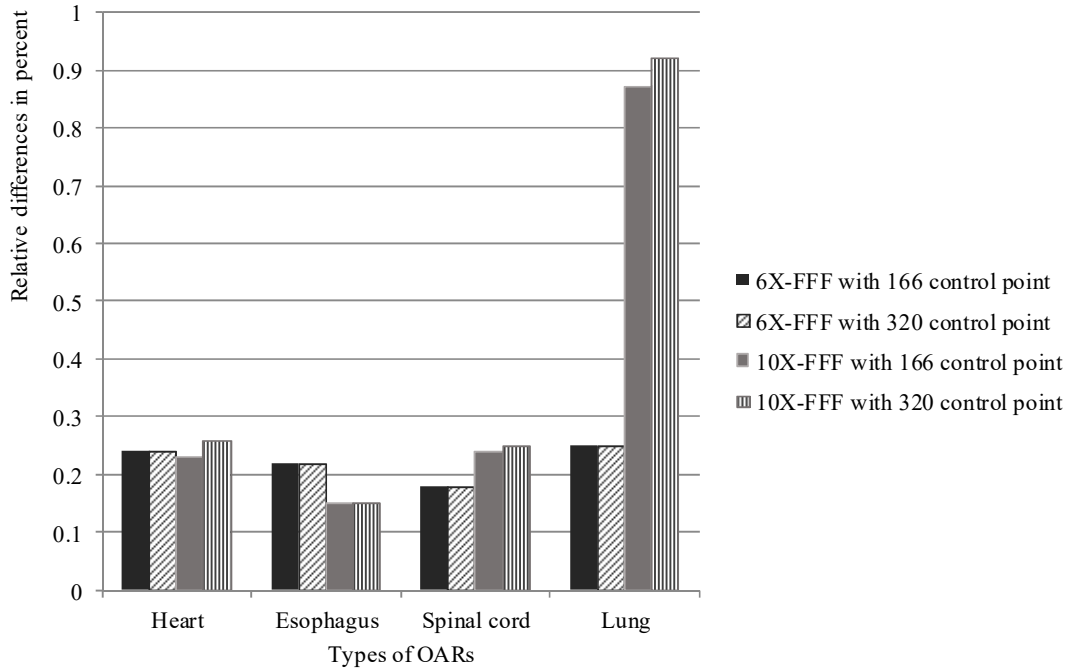| Patient	Energy (MeV)	Computation time (min)			Plan storage space (KB)		
		64	166	320	64	166	320
1	6X-FFF	4.26	4.39	4.38	362	638	633
2	10X-FFF	5.46	5.53	5.54	290	486	493
3	10X-FFF	7.50	8.08	8.04	369	667	657
4	10X-FFF	6.04	6.27	6.28	289	546	546
5	6X-FFF	3.30	3.45	3.48	285	714	801
6	10X-FFF	9.54	10.21	10.21	375	780	811
7	10X-FFF	12.59	13.19	13.43	374	819	845
8	6X-FFF	7.02	7.10	7.18	375	554	558

Figure1: The average differences of OARs dose comparing with the 64 control point plans for both 6X-FFF and 10X-FFF photon beams

Table 5: The number of treatment fields and the number of control points per patient per individual treatment field of the lung SBRT patient no 3 and 4

Patient	No of treatment fields	Max no of control points	AVG	Field no.								
				1	2	3	4	5	6	7	8	9
3	9	64	64	64	64	64	64	64	64	64	64	64
		166	118	126	118	117	114	104	119	113	130	122
		320	118	126	118	117	114	104	119	113	130	122
4	7	64	64	64	64	64	64	64	64	64	-	-
		166	124	137	153	117	126	106	109	120	-	-
		320	124	137	153	117	126	106	109	120	-	-

The number of control point has a direct effect on the computation time and the plan storage space. Our results demonstrated the DMLC-IMRT plan with a larger number of control point require a longer time for calculation and more space for file storage as summarized in Table 4. Comparing with the 64 control point, the largest increasing of computation time is 0.67 and 0.84 minutes using the 166 and 320 control points for the 10X-FFF beam, respectively. It is found to be proportional to the number of control points per individual treatment field and the number of treatment fields as presented in Table 5.

An equivalent diameter of the PTV for the plan number 3 and 4 equals to 5.1 cm, but the number of treatment fields is different. We found that the higher number of treatment field, the lower number of average control point (AVG). Moreover we observed that the size of treatment plan increases in the similar ratio with the increasing of an AVG. Goraj *et al*[5] reported that the number of control points associates with the plan storage space and the file transfer error. Therefore choosing an optimal number of maximum control points for practical dose calculation is an appropriate parameter for balancing the plan quality, computation time and file size.

5. Conclusion

Data analysis of target coverage and OARs showed no clinically significant in dose when varied the maximum control point number. Using the 166 control point can yield a lower dose distribution in PTV and OARs for both 6X-FFF and 10X-FFF photon beams, however it requires a longer computation time and a more space for plan storage.

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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