Comparison of Treatment Plans with Multileaf Collimators of Different Leaf Widths

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We compared intensity-modulated radiotherapy (IMRT) treatment plans with commercially available multileaf collimators (MLCs) of different leaf width for intracranial lesions. Twelve cases previously treated with micro-MLCs (mMLCs) were replanned using the Varian 120 and 80 MLCs. These collimators have minimum leaf width of 3 mm, 5 mm and 10 mm at isocenter, respectively. These three plans were compared with respect to the uniformity and the conformity indices, doses to normal tissue. For the uniformity index of planning target volume (PTV), there was no statistically significant difference between mMLCs with 120 MLCs (p = 0.06). However, there was a little difference between mMLCs with 80 MLCs (p = 0.001). Maximum target dose to the PTV showedno dependency with respect to the leaf width. On the contrary, there were statistically significant differences in the conformity indices between mMLCs and 120 MLCs (p = 0.003) and between mMLCs and 80 MLCs (p = 0.003). The volumetric increments for MLCs with leaf widths of 5 mm and 10 mm were 6.3% and 23.2% for the normal tissue irradiated to = 50% dose, and 8.7% and 32.7% for the normal tissue irradiated to = 70% dose, respectively, compared to the volume for MLCs with leaf width of 3 mm. This shows that for the sparing of normal tissue, MLCs with leaf width of 3 mm are more effective, compared to MLCs with leaf widthsof 5 mm and 10 mm.

Key words: multileaf collimators (MLCs), uniformity index, conformity index, sparing of normal tissue

INTRODUCTION

Intensity-modulated radiotherapy (IMRT) for intracranial lesionsinvolves the precise delivery of a dose of ionizing radiation. Because of the importance of nurological structures and their sensitivity to radiation, normal tissue sparing is one of the key goals of a radiosurgery procedure. Recent advances in multileaf collimator (MLC) technology have provided clinicians with the ability to shape a radiosurgery beam and thereby deliver a homogeneous target dose while simultaneously sparing critical organs.

MLCs are used instead of the conformal blocks due to their efficiency in treatment delivery, although the target conformity is limited by the discrete step size of the leaves. Adams *et al.* [1] compared treatment plans, in terms of normal tissue doses and tomour coverage, for fields shaped using conformal blocks and conventional MLCs and reported that the plan by MLCs showed increased volume of normal tissue being treated to > 50% and > 80% of the prescription dose.

Comparisons of plans with MLCs with different leaf widths have been studied previously. Kubo *et al.* [2] reported that for prostate cancer, MLCs with 1.7 and 3.0 mm leaf widthsspare more bladder and rectum than 10.0 mm leaf width MLC. Recently, comparison studies for MLCs with a leaf width of 3 mm and5 mm using 3D-CRT plan [3], 5 mm and 10 mm using IMRT plan [4] were reported.

In this study, IMRT plans were compared for different MLCs having leaf width of 3 mm, 5 mm and 10 mm at isocenter, respectively. These three plans were compared with respect to the uniformity and the conformity indices, doses to normal tissu

MATERIALS AND METHODS

Multileaf Collimator systems

The BrainLAB micro-MLCs (mMLCs) were a conveniently detachable unit to linear accelerators which did not have a built-in MLC. It had 26 pairs of leaves and a maximum field size of 10 cm 10 cm. The leaf width at isocenter was 3 mm for the central 14 pairs, 4.5 mm for the other 6 pairs, and 5.5 mm for the outermost 6 pairs. Similar to the Varian MLCs, the BrainLAB mMLCs were compatible with Varian C series linear accelerators. The Varian 120 MLCs had a leaf width of 5.0 mm at isocenter for the 40 pairs, 10 mm for the other 20 pairs and a maximum field size of 40 cm 40 cm. The Varian 80 MLCs had a uniform leaf width of 10.0 mm for the 40 pairs and a maximum field size of 40 cm 40 cm.

Treatment Planning and Evaluation

All treatment planning was carried out using the Brain-SCAN ver. 5.2. software. Each patient was computed tomography (CT) scanned with 2 mm contiguous slices. Magnetic resonance (MR) scans with Gd contrast were acquired with contiguous slices of 23 mm thickness, depending on target size. These were fused using this planning software automatically.

IMRT treatment planning is a computer optimization process based on a set of dose constraints on various critical structures and prescribed doses to the tumor targets. There are two types of dose constraintsin this planning system. One is PTV constraints, the other is organ at risk (OAR) constraints. Under the restrictions of dose constraints, inverse planning process is tring to deliver suitabledoses to PTV and critical organs.

The dose distribution calculation is based on a pencil beam algorithm and is normalized to 100% at isocenter. Dose volume histograms (DVHs) for the PTV and normal tissue are calculated and used to evaluated plan. For quatitative evaluation of plan, the uniformity and the conformity indices are used. The uniformity index for PTV is defined as the ratio between the PTV maximum dose and D95, the dose received by 95% of the target volume. The conformity index, as defined on the BrainSCAN DVH, is the ratio of the total tissue volume receiving the prescription dose to the volume of PTV receiving the prescription dose.

Comparison between MLCs for different leaf widths

Treatments using BrainLAB mMLCs were replanned using the Varian 120 and 80 MLCs. The number, direction, and weighting of the beams and the collimator angle were all unchanged in order to compare the plan of mMLCs with the plans of the Varian 120 and 80 MLCs. Parameters used to compare the m3, 120-leaf and 80-leaf plans were the uniformity index for PTV, maximum target dose, the conformity index, the dose received by normal tissue. Statistical significance of each comparison was evaluated using Wilcoxon signed rank test. (p value $\sim$0.05)

RESULTS AND DISCUSSION

Uniformity index and maximum target dose

The uniformity index of PTV is determined from the DVH curves for each plan in Fig. 1, and summarized in Table 1. There was no statistically significant difference between mMLCs with 120 MLCs (p = 0.06) and between 120 MLCs and 80 MLCs (p = 0.388). However, there was a little difference between mMLCs with 80 MLCs (p = 0.001). For the maximum target dose to the PTV, there is no dependency with respect to the leaf width. (mMLCs : 120 MLCs (p = 0.388), mMLCs : 80 MLCs (p = 0.227), 120 MLCs : 80 MLCs (p = 0.774))

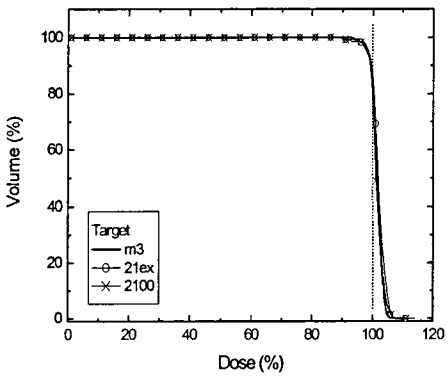

Fig. 1. DVH of PTV for a patient

Table1. Uniformity index and maximum target dose

patient list	uniformity index			maximum target dose (Gy)		
	m3	120-leaf	80-leaf	m3	120-leaf	80-leaf
1	1.05	1.10	1.08	2.12	2.22	2.18
2	1.07	1.06	1.08	8.03	7.95	7.95
3(1)	1.12	1.16	1.15	8.25	8.55	8.47
3(2)	1.08	1.09	1.09	7.95	8.03	8.03
4	1.05	1.06	1.07	7.42	7.49	7.56
5	1.04	1.03	1.04	20.40	20.20	20.40
6	1.26	1.23	1.27	2.32	2.26	2.32
7	1.19	1.22	1.21	2.10	2.10	2.08
8	1.07	1.09	1.10	4.32	4.32	4.28
9	1.09	1.13	1.13	4.32	4.44	4.32
10	1.11	1.12	1.16	3.21	3.18	3.24
11	1.10	1.14	1.15	2.12	2.18	2.16
12	1.07	1.12	1.13	5.40	5.65	5.70
avg	1.10	1.12	1.13	6.00	6.04	6.05
SD	0.06	0.06	0.06			

Conformity index

The conformity index, which is summarized in Table 2, shows different feature. There are statistically significant differences in the conformity indices between mMLCs and 120 MLCs (p= 0.003) and between mMLCs and 80 MLCs (p = 0.003). This shows that the conformity index is increased a little as the leaf width increased.

Dose to normal tissue

Table 3 shows the volumes of normal tissue irradiated to = 50% and = 70% dose for plans with MLCs of different leaf widths. As expected from the Table 3 related to conformity index, the volumes of normal tissue irradiated are increased as the leaf width increased. The volumetric increments for MLCs with leaf widths of 5 mm and 10 mm were 6.3% and 23.2% for the normal tissue irradiated to = 50% dose, and 8.7% and 32.7% for the normal tissue irradiated to = 70% dose, respectively, compared to the volume for MLCs with leaf width of 3 mm. This means that the smaller leaf width of MLCsprovides better sparing for normal tissue.

Table2. Conformity index

patient list	conformity index		
	m3	120-leaf	80-leaf
1	1.22	1.23	1.31
2	1.44	1.63	1.85
3(1)	1.64	1.72	1.83
3(2)	2.64	2.69	3.26
4	1.53	1.67	1.77
5	1.84	2.12	2.25
6	1.15	1.17	1.18
7	1.00	1.00	1.00
8	1.30	1.35	1.40
9	1.77	1.80	1.93
10	1.23	1.59	2.52
11	1.34	1.21	1.16
12	1.42	1.62	1.70
avg	1.50	1.60	1.78
SD	0.42	0.45	0.63

Table3. Dose to normal tissue

patient list	% vol.≥70% of dose			% vol.≥50% of dose		
	m3	120-leaf	80-leaf	m3	120-leaf	80-leaf
1	26.45	25.27	33.52	46.87	45.62	56.38
2	6.64	8.16	9.81	11.47	13.83	16.77
3	7.43	8.53	10.62	13.75	14.87	18.72
4	3.39	4.18	5.25	5.84	7.36	9.12
5	1.66	2.30	3.37	3.07	3.87	5.57
6	33.17	31.22	33.55	70.46	64.91	67.04
7	5.92	6.20	7.28	14.25	15.79	17.98
8	6.08	7.67	10.54	12.61	15.07	19.23
9	3.59	5.25	7.27	7.20	10.13	13.52
10	6.63	9.47	12.38	13.81	18.01	22.52
11	11.93	13.05	14.60	25.06	26.75	29.71
12	4.04	5.75	6.78	8.14	10.99	12.28
avg	9.74	10.59	12.91	19.38	20.60	24.07

CONCLUSIONS

We compared IMRT treatment plans with MLCs of different leaf widths. Leaf width dependency for different MLCs by the uniformity index was not found in this study. Although maximum target dose wasindependent of leaf width of MLCs, the conformity index and the volumes of normal tissue irradiated were increased as the leaf width of MLCs was increased. This imples that for the sparing of normal tissue, MLCs with leaf width of 3 mm are more effective, compared to MLCs with leaf widths of 5 mm and 10 mm.

ACKNOWLEDGEMENTS

This investigation was supported by a research grant from the National Cancer Center, Korea (no. 0410310).

REFERENCES

1. Adams EJ, Cosgrove VP, Shepherd SF, *et al.* Comparison of a multi-leaf collimator with conformal blocks for the delivery of stereotactically guided conformal radiotherapy. Radiother Oncol 1999; 51:205209.
2. Kubo HD, Wilder RB, Pappas CTE. Impact of collimator leaf width on stereotactic radiosurgery and 3D conformal radiotherapy treatment plans. Int J Radiat Oncol Biol Phys 1999; 44:937945.
3. J. E. Monk *et al.* Comparison of a micro-multileaf collimator with a 5 mm leaf width collimator for intracranial stereotactic radiotherapy. Int J Radiat Oncol Biol Phys 2003 57:14431449.
4. J. B. Fiveash *et al.* Effect of multileaf collimator leaf width on physical dose distributions in the treatment of CNS and head and neck neoplasms with intensity modulated radiation therapy. *Med. Phys.* 29,1116 (2002).

Leaf width가 다른 다엽 콜리메터에 의한 치료계획 비교

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Leaf width가 다른 다엽 콜리메터 (MLCs)를 이용한 강도변조 방사선 치료 (IMRT)계획을 비교하였다. micro-MLCs를 사용하여 이미 시행된 12 case를 Varian사의 120 MLC와 80 MLC를 사용하여 다시 치료계획 하였다. 이들 콜리메터는 중심에서의 leaf width가 각각 3 mm, 5 mm, 10 mm이다. 이 치료계획들을 uniformity index, conformity index, 정상조직 내 선량으로 서로 비교하였다. PTV의 uniformity index경우, mMLCs와 120 MLCs가 통계적으로 차이가 없었다 ($p = 0.06$). 그러나 mMLCs와80 MLCs는 통계적으로 약간의 차이를 보였다 ($p = 0.001$). PTV에 대한 최대목표선량은 leaf width와 연관성이 없었다. conformity index의 경우, mMLCs와 120 MLCs ($p = 0.003$)에서, mMLCs와 80 MLCs ($p = 0.003$)에서 통계적인 차이를 보였다. leaf width의 변화에 따라 방사선에 조사되는 정상조직의 부피를 비교하였고, leaf width가 3 mm인 경우 정상조직 보존에 보다 적합함을 확인하였다.

중심단어: 다엽 콜리메터 (MLCs), uniformity index, conformity index, 정상조직 보존