Oncology and Translational Medicine
DOI 10.1007/s10330-014-0042-z

August 2015, Vol. 1, No. 4, P186–189

ORIGINAL ARTICLE

Dosimetric comparison of different multileaf collimators in volumetric modulated arc therapy for malignant pleural mesothelioma

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Abstract

Objective The aiom of the study was to compare the impacts of two types of multileaf collimators (MLC) [standard MLC with a width of 10 mm (sMLC) and micro-MLC with a width of 5 mm (mMLC)] on volumetric modulated arc therapy (VMAT) planning for malignant pleural mesothelioma.

Methods VMAT for ten patients with inoperable malignant pleural mesotheliomas was retrospectively planned with the sMLC and mMLC. Histogram-based dose-volume parameters of the planning target volume (PTV) [conformity index (CI) and homogeneous index (HI)] and organs-at-risk were compared for VMAT plans with sMLC (sMLC-VMAT) and mMLC (mMLC-VMAT).

Results The mMLC-VMAT plans were more efficient (average delivery time: 2.67±1.49 min) than the sMLC-VMAT plans (average delivery time: 4.21 ± 2.03 min; $P < 0.05$). Moreover, compared to the sMLC plans, the mMLC plans demonstrated advantages in the dose coverage of the PTV (CI 0.75 ± 0.08 vs 0.73 ± 0.09; HI 1.09 ± 0.02 vs 1.10 ± 0.02), although the difference was not statistically significant ($P > 0.05$). In addition, significant dose sparing in the fraction of the ipsilateral lung volume receiving > 20 Gy (V20; 54.72 ± 27.08 vs 58.52 ± 29.30) and > 30 Gy (V30; 42.74 ± 27.86 vs 46.86 ± 31.49) radiation, respectively, was observed for the mMLC plans ($P < 0.05$).

Conclusion Comparing sMLC-VMAT and mMLC-VMAT not only demonstrated the higher efficiency and better optimal target coverage of mMLC-VMAT, but also considerably improved the dose sparing of the ipsilateral lung in the VMAT plans for malignant pleural mesothelioma.

Received: 23 December 2014
Revised: 12 January 2015
Accepted: 25 January 2015

Key words: multileaf collimator (MLC); mesothelioma; volumetric modulated arc therapy (VMAT)

Malignant mesothelioma is a very serious disease. The contemporary treatment in operable cases involves a combination of neoadjuvant chemotherapy, extrapleural pneumonectomy, and postoperative radical radiation therapy. In these patients, intensity modulated radiation therapy (IMRT) techniques are used to achieve a better therapeutic ratio [1–5]. However, most cases are inoperable due to various reasons and require radical or palliative radiation therapy.

In this study, a newer radiotherapy technique, volumetric modulated arc therapy (VMAT), was evaluated for the treatment of inoperable malignant pleural mesothelioma (MPM) patients. We compared the impact of two different multileaf collimator (MLC) widths on VMAT plans for MPM. All VMAT plans were generated for two Elekta commercial MLC devices using the Monaco treatment planning system (version 5.0, Elekta AB, Sweden).

Materials and methods

Multileaf collimators

The standard MLC (sMLC) was the MLC device equipped with the Elekta Synergy Treatment System (Elekta Oncology System, Sweden). The leaf width of this MLC was 10 mm at its isocenter. It has 40 leaf pairs, upper jaws, and backup jaws and covers a full 40 cm × 40 cm field. The total leaf travel distance was 32.5 cm. There is a minimum leaf gap across the banks.

The micro-MLC (mMLC) is another commercial Elekta system, the Elekta Axesse (Elekta Oncology Systems,

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Table 1 HI and CI of sMLC-VMAT and mMLC-VMAT

	sMLC-VMAT	mMLC-VMAT	*t* value	*P* value
HI	1.10 ± 0.02	1.09 ± 0.02	1.309	0.223
CI	0.73 ± 0.09	0.75 ± 0.08	-1.677	0.128

UK). It consists of 80 opposed pairs of leaves. Each individual leaf was capable of interdigitation and projects a width of 5 mm at the isocenter. The maximum allowable field size was also 40 cm × 40 cm.

Patient selection, positioning, and CT scanning

Ten MPM patients treated with routine IMRT between September 2006 and May 2013 were chosen for this retrospective analysis. The mean and median age was 50.1 and 51.5 years, respectively. A computed tomography (CT) scan of each patient in the treatment position was obtained using a helical CT scanner (Brilliance Big Bore CT, Philips Medical systems, USA) with a slice interval and thickness of 5 mm. The CT scans were obtained from the level of the larynx to the level of the upper abdomen and were imported into the Monaco planning system (version 5.0, Elekta AB, Sweden). Intravenous contrast was administered to all patients before performing a CT scan. In addition, to minimize setup variability, a custom immobilization device–thermoplastic mold (MedTec)–was fabricated for each patient in the supine position.

Target volumes and critical structures

The delineation of target and critical structures for all patients was done on individual CT slices by a single radiation oncologist with extensive experience in the treatment of MPM. According to the International Commission on Radiation Units and Measurements report 62 [6] and other published studies [7], the gross target volume (GTV) included the affected pleural lesions and mediastinal lymph nodes. The planning target volume (PTV) was determined using a 5-mm uniform expansion of the GTV. The prescribed dose for the PTV was 60 Gy in 2 Gy daily fractions. Organs-at-risk (OARs) included the lungs, spinal cord, and heart.

Treatment planning

All plans were designed using 6 MV photon beams of the Elekta Synergy accelerator and Elekta Axesse accelerator (Elekta AB, Sweden) on the Monaco planning system (version 5.0, Elekta AB, Sweden). For each patient, two VMAT plans (one with sMLC called sMLC-VMAT and the other with mMLC called mMLC-VMAT) were generated using 2 full arcs of clockwise rotations from the initial angle of 180 degrees to the end angle of 180 degrees. All plans were normalized to cover 95% of the PTV with the prescribed dose using an identical set of PTV and OARs dose-volume constraints. The dose-volume constraints used for the targets and critical structures were based on clinical experience from our clinic and kept identical for all plans.

Plan comparisons

Dosimetric comparisons of the plans were based on the following parameters extracted from the dose-volume histogram: homogeneity index (HI); conformity index (CI); fraction of the ipsilateral lung volume receiving > 5 Gy, 10 Gy, 20 Gy, 30 Gy, respectively (V5, V10, V20, V30); V5 and mean dose (Dmean) of the heart; V3, V5, V10, and V20 of the contralateral lung; and maximum dose (Dmax) of the spinal cord. The HI was used to analyze dose uniformity and defined as D5/D95 (minimum dose in 5% of the PTV/minimum dose in 95% of the PTV). The lower the HI, the better the dose homogeneity. The CI measured the degree of conformity and was calculated as follows [8]: the percentage of the PTV receiving the prescribed dose × the ratio of the PTV receiving the prescribed dose to the total 60 Gy volume. The closer the CI value was to 1, the better the dose conformity.

Statistical analysis

Statistical analysis was performed using SPSS software (version 18.0, SPSS Inc., USA). Quantitative data were expressed in the form of mean ± standard deviation. The significance of differences was tested using a paired two-tailed Student's t test and 95% confidence intervals were calculated. A value of $P \leq 0.05$ was considered statistically significant.

Results

Comparison of the HI and CI of the PTV

The HI and CI for the comparison of the two techniques are presented in Table 1. No significant difference for HI and CI was found ($P = 0.223$, $P = 0.128$).

Comparison of the dosimetric parameters for OARs in two modalities

The dosimetric parameters for normal tissues including the ipsilateral lung, heart, contralateral lung, and spinal cord were listed in Table 2. The V20 and V30 of the ipsilateral lung showed significant differences ($P = 0.031$, $P = 0.033$, respectively). mMLC-VMAT reduced the irradiated volume of the ipsilateral lung in high dose areas, while the V5 and V10 demonstrated no significant differences ($P = 0.285$, $P = 0.089$, respectively). For the V5 and Dmean of the heart, no significant differences were observed ($P = 0.083$, $P = 0.207$, respectively). No significant difference existed between sMLC-VMAT and mMLC-VMAT in the V3, V5, V10, and V20 of the contralateral lung ($P = 0.740$, $P = 0.575$, $P = 0.455$, $P = 0.319$, respectively). For the spinal cord, no significant difference was found between the

Table 2 Comparison between the dosimetric parameters of the OARs for two techniques

OARs	Dosimetric parameters	sMLC-VMAT	mMLC-VMAT	*t* value	*P* value
Ipsilateral lung	V5	83.52 ± 20.61	82.61 ± 21.51	1.138	0.285
	V10	75.95 ± 24.37	73.56 ± 25.38	1.907	0.089
	V20	58.52 ± 29.30	54.72 ± 27.08	2.549	0.031
	V30	46.86 ± 31.49	42.74 ± 27.86	2.509	0.033
Heart	V5	71.76 ± 44.91	71.28 ± 45.28	1.951	0.083
	Dmean	21.23 ± 15.33	20.36 ± 15.13	1.361	0.207
Contralateral lung	V3	80.26 ± 25.65	80.11 ± 26.35	0.342	0.740
	V5	73.06 ± 30.63	73.59 ± 30.21	-0.582	0.575
	V10	46.09 ± 22.90	47.90 ± 27.39	-0.781	0.455
	V20	11.51 ± 11.65	12.81 ± 11.78	-1.054	0.319
Spinal cord	Dmax	36.69 ± 11.07	36.22 ± 10.97	0.642	0.537

Note: V5, V10, V20, V30, and V40 mean the fraction of OAR volume receiving > 5 Gy, 10 Gy, 20 Gy, 30 Gy, and 40 Gy, respectively.

Table 3 Comparison of monitor units and treatment delivery time

	sMLC-VMAT	mMLC-VMAT	*t* value	*P* value
MUs	868.9 ± 396.1	962.1 ± 489.2	-2.019	0.074
Time (min)	4.21 ± 2.03	2.67 ± 1.49	3.779	0.004

Dmax of both the techniques ($P = 0.537$).

Monitor units (MU) and treatment delivery time comparison

The MUs and treatment delivery time associated with sMLC-VMAT and mMLC-VMAT were shown in Table 3. mMLC-VMAT has higher MUs, but lower delivery time.

Discussion

Improved technologies that enhance dose conformity while avoiding dose delivery to critical structures has opened ways of treating complex oncological situations, such as MPM. The radiotherapy of MPM patients is commonly performed by IMRT, with improved dose conformity and homogeneity for the target in comparison to three-dimensional conformal radiotherapy [2]. However, a major drawback of IMRT is the longer treatment time, which is due to the large number of monitor units. In the VMAT technique, continuous delivery is achieved by simultaneously varying the dose rate, the positions of the multileaf collimator, and the gantry rotation speed. Compared to IMRT, VMAT reduces MU usage and treatment delivery time from 10 min to 4 min [9], which is consistent with the delivery time in our study. As reported previously [10], the decrease in treatment time reduces patient motion during the treatment delivery and thus, results in greater agreement between the planned dose and the dose delivered. This reduction in treatment time will decrease the time that the patients have to remain in an uncomfortable position on their back with arms above the head. No major differences were seen between the doses to the OARs for sMLC-VMAT and mMLC-VMAT, except for the V20 and V30 of the ipsilateral lung. A reduction by a factor of 1.1 for V20 and V30, respectively, for the ipsilateral lung was observed for mMLC-VMAT. This dose reduction for the lung could decrease the risk of complications, such as radiation-induced pneumonitis, where rates larger than 40% have been reported [11]. The dose conformity and homogeneity were not statistically different for sMLC-VMAT and mMLC-VMAT in our study. Nevertheless, the small difference between the target coverage of sMLC-VMAT and mMLC-VMAT, and the dose homogeneity on the planning CT scan does not imply an identical dose delivery to the target during all treatment sessions.

Conclusions

Compared to VMAT with sMLC, VMAT with mMLC enhances the treatment quality with photons by reducing the ionizing radiation dose delivered to the ipsilateral lung. It also saves treatment time and the integral dose, which may be conducive to decreasing the occurrence of radiation pneumonitis.

Conflicts of interest

The authors indicated no potential conflicts of interest.

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DOI 10.1007/s10330-014-0042-z
Cite this article as: Zhang FL, Jiang HY, Xu WD, *et al*. Dosimetric comparison of different multileaf collimators in volumetric modulated arc therapy for malignant pleural mesothelioma. Oncol Trans Med, 2015, 1: 186–189.