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EXTENDED ABSTRACT

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Micro-multileaf collimator for stereotactic radiosurgery: A retrospective plan quality metrics comparison to multileaf collimator

Sílvia Leitão[1,2,3], Sara Velha[1,2,4], David Faria[1,2], Fernando Costa[1], Joana Vale[3]

[1] Serviço de Radioncologia, Lenitudes – Centro Médico Avançado, Santa Maria da Feira, Portugal
[2] Mercurius Health, S.A., Lisbon, Portugal
[3] School of Health, University of Aveiro, Aveiro, Portugal
[4] Department of Mathematics, University of Aveiro, Aveiro, Portugal

Introduction

Stereotactic radiosurgery (SRS) is a high precision technique, characterized by high levels of conformity and steep dose gradients from the edge of the target volume to adjacent organs, allowing delivery of a high dose of radiation in a single fraction [1]. In our institution SRS treatments are delivered using a digital linear accelerator equipped with a 5 mm leaf width multileaf collimator (MLC), with a non-invasive frameless immobilization system. The aim of this study was to evaluate if the change to the add-on micro-MLC (μMLC) with 2.5 mm leaf width, though it requires an increase in setup and treatment times, would improve the plan quality metrics, compared to the delivered plan with MLC.

Methods

A total of 30 plans for patients with single intracranial lesion (5 brain metastases, 13 meningiomas and 12 neurinomas) treated with volumetric modulated arc therapy (VMAT) SRS between October 2018 and December 2019 were retrospectively reviewed. Treatment plans were calculated with a Monte Carlo based dose calculation algorithm for MLC. Comparative plans were recalculated for the μMLC, using the same arc configuration and optimization cost functions.

Clinical cases for which micro-MLC plans target coverage were inferior to the clinical accepted coverage for SRS treatment, were excluded from the analysis, as they are not a part of the study objective.

Plan quality metrics were compared between μMLC and MLC with respect to target coverage (TC) [2], homogeneity index (HI) [3], ratio of maximum dose to prescription dose (MDPD) [4], conformity index (CI) [4], conformation number (CN) [5,6] and gradient index (GI) [7]. All quantitative variables were tested for normality (Shapiro-Wilk test) and symmetry to determine if statistical test assumptions are met. Due to the presence of outliers and as most of the quantitative variables violated the assumption of normality, statistical differences between medians were evaluated using a Wilcoxon signed rank test (paired sample sign test), considering a result statistically significant for a two-tailed p-value < 0.05 and reporting a confidence interval with 95% assurance level (95% CI). The Cohen's d effect size was determined for variables that indicated statistically significant differences. Statistical analysis was performed using software RStudio (version 3.6.1).

Results

Patients were treated with a prescription dose of 12 to 20 Gy in a single fraction and 80% (n = 24) of the lesions included in the initial review were irregular, with gross tumor volume ranging from 0.06 to 15.21 cm^3 (median: 2.68 cm^3) (Table 1). For the 30 VMAT SRS plans, collimators showed comparable results in terms of coverage ($p = 0.84$, $n = 60$) and clinical coverage objective for SRS treatment was met in 97% (n = 29) of the μMLC plans (Figure 1). In accordance with our exclusion criteria, a new data set was generated, eliminating this plan from the analysis of plan quality metrics.

Micro-MLC revealed no significant difference in median homogeneity index ($p = 0.71$, 95% CI -0.01 to 0.01), ratio of maximum dose to prescription dose ($p = 0.06$, 95% CI -0.022 to 0.001), conformity index ($p = 0.69$, 95% CI -0.02 to 0.02) or conformity number ($p = 0.97$, 95% CI -0.01 to 0.01). Compared with MLC,

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Corresponding author:
Sara Velha
sara.velha@lenitudes.pt

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µMLC improved median plan gradient index from 4.96 to 4.83 ($p < 0.001$, 95% CI 0.09 to 0.38, $d = 0.82$) (Table 2). Our data suggest that neurinomas ($d = 1.34$) would benefit considerable from the smaller penumbra of this µMLC, while brain metastases ($d = 0.53$) and meningiomas ($d = 0.67$) would be the less favoured with the change of collimator.

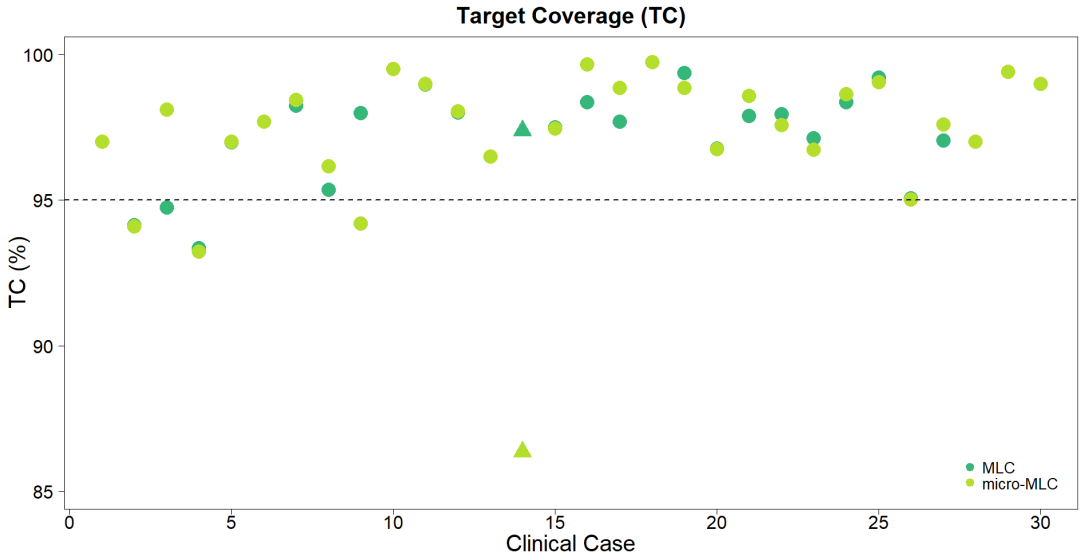

Figure 1 - Target coverage for MLC and micro-MLC for the 30 VMAT SRS plans included in the initial review. The ▲ represents the clinical case excluded from the analysis of plan quality metrics. The dashed line represents the clinical accepted coverage for SRS treatment.

Table 1 - Characteristics of SRS lesions included in the initial review.

Pathology	n	GTV Irregular Shape[a]	GTV (cm³)[b]	PTV (cm³)[b]
Brain metastases	5	2 (40%)	2,59 ± 3,37 (0,81 - 9,10)	5,21 ± 4,37 (2,12 - 12,82)
Meningioma	13	10 (77%)	6,13 ± 3,68 (1,23 - 15,21)	10,82 ± 5,29 (4,58 - 19,64)
Neurinoma	12	12 (100%)	0,95 ± 0,74 (0,06 - 2,95)	1,76 ± 1,10 (0,18 - 4,48)
Total	30	24 (80%)	3,59 ± 3,62 (0,06 - 15,21)	6,26 ± 5,71 (0,18 - 19,64)

GTV, Gross tumor volume; PTV, Plan target volume.
[a]Counts (percentage).
[b]Mean ± standard deviation (range).

Table 2: Plan quality evaluation for MLC and micro-MLC (recalculated) plans for all 29 VMAT SRS patients.

Quality Metrics	Constrains	MLC[a]	micro-MLC[a]	p-valueb	95% CI
TC (%)	**≥ 95%**	97.70 (93.35 - 99.73)	97.70 (93.23 - 99.73)	0.57	[-0.39, 0.08]
HI	**close to 0**	0.23 (0.14 - 0.39)	0.24 (0.14 - 0.35)	0.71	[-0.01, 0.01]
MDPD	**≤ 1.5**	1.30 (1.19 - 1.38)	1.32 (1.18 - 1.40)	0.06	[-0.022, 0.001]
CI	**< 1.2 (1-2)**	1.18 (1.00 - 1.50)	1.18 (1.00 - 1.50)	0.69	[-0.02, 0.02]
CN	**≥ 0.6 (0-1)**	0.80 (0.66 - 0.92)	0.82 (0.67 - 0.92)	0.97	[-0.01, 0.01]
GI	**-**	4.96 (2.49 - 12.50)	4.83 (2.53 - 11.19)	< 0.001	[0.09, 0.38]

[a]Median (range).
[b]Statistical significance at $p < 0.05$.

Discussion and conclusions

SRS delivered to a single lesion in doses of 12 to 20 Gy in one fraction with the add-on µMLC is clinically acceptable in terms of plan quality metrics, offering some advantages compared to MLC with respect to the sparing of adjacent organs, with our data showing a prevailing clinical advantage of the treatment with the µMLC for neurinomas.

To better support the clinical decision on the choice of the collimator system for each treatment, we should increase our sample size for each pathology, in order to evaluate which lesions would benefit from the use of micro-MLC, by studying the dosimetric differences according to tumor shape, volume and location.

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