Treatment planning systems for external whole brain radiation therapy: With and without MLC (multi leaf collimator) optimization

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Treatment planning systems for external whole brain radiation therapy: With and without MLC (multi leaf collimator) optimization

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Abstract. Radiation therapy for brain malignancy is done by giving a dose of radiation to a whole volume of the brain (WBRT) followed by a booster at the primary tumor with more advanced techniques. Two external radiation fields given from the right and left side. Because the shape of the head, there will be an unavoidable hotspot radiation dose of greater than 107%. This study aims to optimize planning of radiation therapy using field in field multi-leaf collimator technique. A study of 15 WBRT samples with CT slices is done by adding some segments of radiation in each field of radiation and delivering appropriate dose weighting using a TPS precise plan Elekta R 2.15. Results showed that this optimization a more homogeneous radiation on CTV target volume, lower dose in healthy tissue, and reduced hotspots in CTV target volume. Comparison results of field in field multi segmented MLC technique with standard conventional technique for WBRT are: higher average minimum dose (77.25% ± 0:47%) vs (60% ± 3:35%); lower average maximum dose (110.27% ± 0.26%) vs (114.53% ± 1.56%); lower hotspot volume (5.71% vs 27.43%); and lower dose on eye lenses (right eye: 9.52% vs 18.20%); (left eye: 8.60% vs 16.53%).

1. Introduction

Radioactive substances are used in radiation therapy as they have been known to kill malignant or cancerous cells. Radiation therapy is usually a combination of surgery and chemotherapy. In general, more than 50% of patients with malignant cells require radiation therapy [1]. The goal of radiation therapy is to give high doses of radiation that is concentrated in the tumor volume and keep the surrounding healthy tissues and organs from being exposed to those high doses of radiation [2].

O In case of a malignancy in the brain, it is usually subject to whole brain radiation therapy (WBRT) followed by radiation to the primary tumor [4]. WBRT is usually done using two opposing radiation fields from the patient's right and left sides, while blocking radiation on the eyes. A radiation dose 3000 cGy is given in 10 fractions or a radiation dose of 4000 cGy given in 20 fractions, 5 fraction/week and a two-day lag time is allowed for the recovery of healthy tissues [2].

External radiation tele therapy must meet the recommendation of the International Commission on Radiation Units and Measurement (ICRU) which says that the entire volume of the target must obtain a homogeneous radiation tolerance of 95-107% [2]. The recommendation is intended to kill tumors with no complications in the healthy tissue and prevent any recurrence due to lack of radiation dose. Excessive doses will result in side effects and complications, whereas less than adequate will result in leftover malignant cells and recurrence [1]. External whole brain radiation usually results in hot spots on thin heads due to excessive dose. Hence, there is the need to find a solution that will provide homogenous radiation for the whole volume of tumor.

2. Methods

A study of 15 WBRT samples with 1 mm CT slice thickness is done by adding some segments of radiation in each field of radiation and delivering appropriate dose weighting using a TPS precise plan Elekta R 2.15 treatment planning computer.

The procedures conducted in this study are; set up the TPS computer, perform data entry, including delineation of the target volume and critical organs by a radiation oncologist, dosimetry calculations, analysis and evaluation of radiation planning, re-planning using MLC optimization method, and the addition of segmentation, create graphs and tables, and finally compare the results with the currently available standard protocol.

3. Results and discussion

3.1. Calculation results of TPS on whole brain radiation therapy using standard protocol

TPS calculation results show that there is a hotspot on a CT scanner slice as shown in figure 1 below.

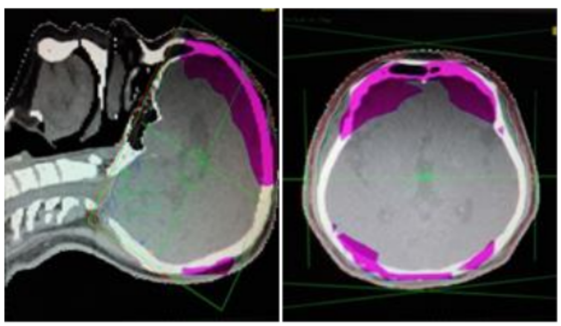

Figure 1. Distribution of whole brain radiation dose using standard protocol.

Red indicates areas receiving a radiation dose ≥ 107% (hot spots), located mainly on the edges of the head that are thinner; top (vertex), front (frontal) and rear (occipital).This sort of radiation planning is not optimum as dose distribution is not even and there is a large hot spot on the target volume. Yet it is still taken as a common practice due to the following reasons:

1. No body compensator or bolus that can be used to modify the curve iso-dosage is available.
2. No MLC on linac machines used for tele therapy is available.
3. No IMRT software that can measure multi-segmented dose is available.
4. The dose given to the whole brain is still low compared to the tolerance limit of brain tissue.
5. The equipment available is not optimally used.

3.2. *TPS results using optimized MLC with radiation field segmentation*

Figure 2 is an example of the same sample that is optimized using a multi-segmented MLC software (Elekta). The hot spot (red/shaded) is significantly narrower, indicating less excessive radiation dose.

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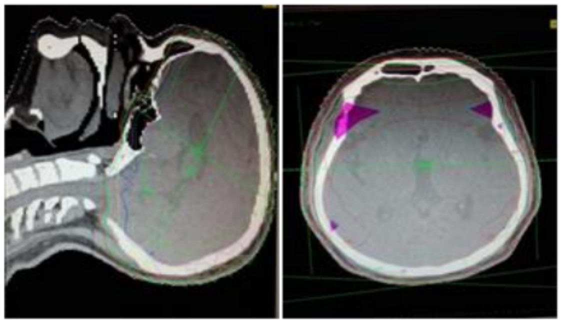

Figure 2. Distribution of whole brain radiation dose using optimized MLC.

3.3. Radiation dose distribution parameters

3.3.1. Homogeneity. Homogeneity of the radiation dose to the target volume is a measure that the radiation given can be concentrated and distributed uniformly on the target tumor. Therefore, all malignant cells are expected to die as radiation doses are sufficient and distributed evenly. The ICRU recommends that homogeneity of radiation dose in an external radiation therapy is in the range of 95% - 107%. Table 1 shows that distribution of radiation dose to the target CTV volume changes with the optimized MLC. D_{min} on PTV increases from 60% ± 3.35% to 77.25% ± 0.47%, D_{max} decreases from 114.53% ± 1.56% to 110.27% ± 0.26%, and D_{mean} decreases closer to the prescribed dose of 100%, from 105.07% ± 1.24% to 102.73% ± 0.26%
Thus, if compared with the standard protocol TPS, the MLC produces smaller variations in optimized dose for PTV and bigger D_{mean} closer to 100%. Hence, PTV dose distribution is more homogeneous.

Table 1. Dose distribution on the brain target volume (CTV).

Pat.	D_{min} (%)		D_{max} target (%)		$D_{average}$ (%)		Hot spot Volume (cc)	
	Standard TPS	Optimized MLC	Standard TPS	Optimized MLC	Standard TPS	Optimized MLC	Standard TPS	Optimized MLC
1	74	76	112	109	105	103	313.23	23.32
2	59	81	115	110	106	102	449.86	34.24
3	53	63	116	110	106	104	443.44	147.45
4	78	87	118	110	106	103	442.78	67.31
5	50	64	115	110	105	102	228.31	97.65
6	51	73	110	109	104	102	202.39	35.58
7	88	90	113	110	104	103	195.81	54.19
8	59	81	115	110	106	102	449.86	70.54
9	46	76	115	111	105	100	348.69	83.64
10	63	84	113	100	104	102	267.42	88.44
11	56	80	112	110	104	103	472.42	67.87
12	86	89	115	111	106	104	458.85	90.43
13	76	84	117	112	106	101	710.29	161.72
14	8	91	114	111	106	104	375.64	111.34
15	75	86	117	113	107	102	404.18	77.89

mean	60	77.25	114.53	110.27	105.07	102.73	384.21	80.77
SD	3.35	0.47	1.56	0.26	1.24	0.26	27.01	7.67

3.3.2. Hot spot. The extent of hot spot could potentially lead to undesirable side effects or complications. More modern equipment is designed to minimize the likelihood of such consequences.

Table 1 shows that the volume of whole brain radiation hotspot for standard protocol is 384.21 cc (27.43% of PTV volume), whereas for optimized MLC, this number shrinks to 80.77 cc (5.71% of PTV volume).

Irradiation using less advanced equipment often results in uneven hot spot distribution, especially on the body surface. This prompts the Radiation Therapy Oncology Group (RTOG) to set a tolerance dose of > 110%, no more than 20% of the dose for the target volume.

3.4. Surrounding healthy tissues/organs

The radiation dose allowed to be taken by the surrounding body tissues/organs is shown in table 2 below.

Table 2. Doses for eyes for both standard protocol and optimized MLC.

Patient No.	Standard TPS		Optimized MLC	
	Right eye (%)	Left eye (%)	Right eye (%)	Left eye (%)
1	9	8	5	5
2	17	17	8	7
3	24	20	9	7
4	29	26	11	10
5	13	9	6	5
6	15	13	7	7
7	22	21	11	14
8	18	15	10	8
9	22	17	15	12
10	17	14	10	9
11	18	22	9	7
12	11	9	10	7
13	18	17	8	9
14	18	23	12	13
15	22	17	7	9
Mean	18.20	16.53	9.52	8.60
SD	1.00	1.11	0.52	0.56

Table 2 shows that radiation doses for eye lenses (organs at risk - OAR) is lower for optimized MLC compared to standard protocol (right eye: 9.52% vs 18.20%); (left eye: 8.60% vs 16.53%).

4. Conclusion

Results of this research show that whole brain radiation therapy using standard protocol cannot prevent the presence of hot spot on the edges of thinner head, as a radiation dose of ≥ 107% is given. They also indicate that compared to standard WBRT radiation, optimized MLC results in smaller hot spot volume. Hence, reducing the risk of both side effects and complications. Furthermore, optimized MLC yields; higher D_{min} (77.25% ± 0:47%) vs (60% ± 3:35%), lower D_{max} (110.27% ± 0:26%) vs (114.53% ± 1:56%), and D_{mean} closer to 100%, (102.73% ± 0:26%) vs (105.07% ± 1:24%). Radiation doses are distributed more evenly or more homogeneous on the target tumor volume. Optimized MLC also produces narrower hot spot on CTV volumes; 80.77 cc (5.71% of CTV volume) vs. 384.21 cc (27.43% CTV of CTV) and finally, optimized MLC gives lower radiation doses on healthy tissues/organs and eye lenses; (right eye: 9.52% vs 18.20%); (left eye: 8.60% vs 16.53%).

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