Intensity Modulated Radiotherapy Versus Three Dimensional Conformal Plan and Dynamic Conformal Arc for Cranial Lesion in Stereotactic Radiothrapy By Using Novalis-Tx System- A Dosimetric Study

B. Goswami, S. Mitra, A.B. Shiva, P. Nagendran, P. Kumari, A. Chakraborty and S. Mukherjee

Department of Radiation Oncology, Apollo Gleneagles Cancer Hospital. Kolkata, India.

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A comparison of the different stereotactic radiotherapy technique in cranial lesion. The primary aim of this study was to judge the quality of the treatment plans.
Twenty-one stereotactic radiotherapy patients of different volume were selected for 3DCRT, DCAT and IMRT on Novalis-Tx. Margin taken for planning target volume (PTV) was 1 mm and the prescribed dose was 95% for all plans. The target coverage at the prescription dose, conformity index (CI), and heterogeneity index, minimal and maximal dose to the planning target volume, coverage index were analyzed for all plans.
If tumor size is small (PTV≤2cc), 3DCRT, DCAT and IMRT plans give approximate values but CI for IMRT plans was high. If tumor size is medium (2cc<PTV≤50cc), 3DCRT, DCAT and IMRT plans give comparative result with each other. The IMRT plans give higher CI, better target coverage at the prescribed dose, better heterogeneity index and better coverage index. If tumors size is large (PTV>50cc), IMRT plan give good target coverage at the prescribed dose.
For small size tumor 3D-CRT and DCAT is useful as IMRT is not recommended. For medium, especially large size tumor IMRT gives better result as well as good sparing of Organ at risk (OARs).

Key words: Intensity-modulated radiotherapy (IMRT), Three-dimensional conformal radiotherapy (3D-CRT), Dynamic conformal arc radiotherapy (DCAT), Organ at risk (OAR) 25.4% ESD reduction for exposures to the abdomen.

1.Introduction

Modern radiotherapy (RT) attempts to improve the dose distribution to conform the high-dose region to the planning target volume (PTV). The implementation of intensity-modulated radiotherapy (IMRT) technique [1] into clinical practice is becoming routine other than cranial lesion by stereotactic radiotherapy. Intensity-modulated RT (IMRT) is a relatively new technique that has the potential to improve the conformal dose distributions and simultaneously increase the protection of organs at risk (OARs) better than is possible with conventional conformal techniques. IMRT may also improve the dose distribution in stereotactic RT (SRT) [2]. The combination of these two techniques is called intensity-modulated SRT (IMSRT). IMRT techniques have been reported to be suited for oddly shaped targets, targets located next to critical structures [3]. Three techniques have been applied in linear accelerator-based fractionated stereotactic radiotherapy for brain tumors: three-dimensional conformal radiotherapy (3D-CRT), (DCAT) and IMRT [4, 5, 6]. Intensity- modulated RT (IMRT) has also been introduced with the advent of the commercial micromultileaf collimator [7] and treatment planning systems. Dynamic conformal arc therapy can offer highly conformal dose distributions for different sites, and the planning is sometimes faster than for 3D-CRT. However, most commercial planning systems for DCAT use forward planning methods, IMRT can allow steep dose gradients between a target and a nearby dose-limiting structure. IMRT resulted in improved dose conformity and decreased

*Corresponding author email: brijeshccs@rediffmail.com

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the dose to non target brain tissue. Compared IMRT plans generated on the "iplan" verson4.1 (BrainLAB treatment planning system, Germany) with those for 3D-CRT & DCAT for the treatment of tumors in the brain. They concluded that IMRT was typically advantageous in terms of planning target volume (PTV) coverage [8], especially for irregular and concave targets, but the volume of normal tissue receiving a low dose can be larger with IMRT. In this study, we investigated the dosimetric differences among 3D-CRT, DCAT, and IMRT plans for a broad range of brain tumor volumes.

2. Methods and Materials

The scanning parameters used in this study were as follows: distance between scans 2mm in CT and 1 mm in MRI. The images were transferred to the treatment planning system and co-registered [9]. The PTV was defined using the information of all three data sets, encompassing the gross tumor volume, clinical target volume, and 1.5mm to 2mm margins. The number of beams varied between five and seven with single isocenter. Usually, a margin of 2mm to 2.5mm was added to all fields beyond the projected PTV. A total dose of 54 Gy was delivered with a dose/fraction of 1.8 Gy, five fractions weekly. The dose was normalized to the isocenter.

In this study, the beam numbers in the 3D-CRT or IMRT plans were the same as the arc numbers in the DCAT plans, and the gantry angle of each beam in the 3D-CRT or IMRT plans was at the middle angle of each arc in the DCAT plans.

The minimal and maximal doses to the PTV were directly read from the DVH. Conformity index (CI), defined in the BrainLAB treatment planning system as

$$CI = 1 + Vn / Vt$$

where Vn and Vt are the volume of the normal tissues and target receiving the prescription dose, respectively.

HI is defined as the ratio of $D_{5\%}$ to $D_{95\%}$ for the PTV:

$$HI = D_{5\%} / D_{95\%}$$

where D5% and D95% correspond to the dose delivered to 5% and 95% of the PTV, respectively. A smaller CI or HI implies a better plan. If both CI and HI were 1.0 the plan would be perfect[10].

The CovI was defined by the volume of PTV receiving equal to, or more than, the indicated dose [$V_{D\ ind}$ (PTV)], divided by the PTV volume [V (PTV)]:

$$Cov\ I = [V_{D\ ind}(PTV) / V(PTV)]$$

3. Results

The selected patients were divided into three groups on the basis of the tumor volume and tabulated in Table 1:

- Group 1, smaller targets (PTV≤2cc);
- Group 2, medium targets (2cc<PTV≤50cc); and
- Group 3, larger targets (PTV>50cc).

Figure 1 shows the CI, and Figure 2 the HI, Figure 3 shows the target coverage for the prescription dose reset to 95% (TV95%); for all plans.

We compared the average values of the dosimetric parameters for the three volume groups among the different plans (Table 2).We observed that for the smaller brain tumors, the TV95%, CI, and HI were roughly equal for the 3D-CRT and DCAT plans, and the CI and HI values were acceptable (CI and HI ≤2.0), and the TV95% values were inferior to those for the IMRT plans.

For the medium size brain tumors, the three plans were competitive with each other. All the dosimetric parameters of the DCAT plans were slightly better than those for 3D-CRT. The IMRT plans had greater CI values and better TV95%and HI values.

For the larger brain tumors, the IMRT plans were the better in TV95%, HI values and the CI values, although both 3D-CRT and DCAT plans were also acceptable.

Thus IMRT plans not only had better dosimetric parameters for the target dose, but also spared more of the critical structures [11] compared with the 3D-CRT and DCAT plans.

Table 1: Twenty One patients selected for dosimetric study			
Group	*Pt. No*	*PTV(CM3)*	*Tumor Site*
1(<2cc)	1	1.79	Trigeminal Neuralgia
	2	1.99	Left basifrontal cavernous hemangioma
2(<50cc)	3	24.37	Non functioning pituitary gland mcroadenoma post op with residual
	4	34.75	Meningioma
	5	15.65	Left tentorial meningioma
	6	22.9	Left frontal meningioma
	7	12.66	Left acoustic neuroma
	8	15.83	Left cp angle schwannoma /o with residual
	9	3.69	Left basifrontal cavernous hemangioma
	10	10.08	Right vestibular schwanoma
	11	4.09	Recurrent pituitary adenoma
	12	16.6	Residual P/O pituitary macroadenomas
	13	3.34	Residual pituitary adenoma
	14	25.51	Residual P/O pituitary macroadenomas
	15	3.87	Recurrence in right vestibular schwannoma
	16	20.25	Low grade astrocytoma of pineal body & tectal plates
	17	6.98	Rosai dorfman disease p/o recurrence
	18	9.98	Residual P/O pituitary macroadenomas
	19	44.14	Chordoma of clivus & sphenoid sinus
3(>50cc)	20	52.05	Fibroblastic meningioma of right cavernosus & sphenoid
	21	78.23	Left mastoid paraganglioma

4. Discussion

In this study, we found that the DCAT plans had dosimetric advantages for most cases in the treatment of brain tumors. Only for complicated cases in which a large target overlapped with critical structures did the DCAT plan not spare enough of the organs at risk compared with the IMRT plan. That was probably because DCAT planning uses a forward planning method, which cannot achieve the full potential of the IMRT technique, which uses inverse treatment planning. DCAT can meet better the dosimetric requirements if an overlapped arcs approach, similar to a field-within-field arrangement, is applied in the clinic.

The 3D-CRT plans were still competitive for the small brain tumors, although the dosimetric parameters of the 3D-CRT plans were a little worse compared with those for the DCAT plans. The number of beams in the 3D-CRT plans was chosen to be the same as the number of arcs in the DCAT plans in this study. However, the beam number in 3D-CRT planning (e.g., seven to eight beams) is usually more than the arc number in DCAT planning (e.g., about five arcs) in the clinic.

Intensity-modulated radiotherapy was not recommended for treating a small brain tumor (PTV<2 cm3). As with most optimization algorithms, the dynamically penalized likelihood algorithm used for inverse planning for BrainLAB IMRT optimizes the weights of beamlets in each field. For a small brain

Table 2: Plan comparison										
PTV Grp	*Pt No.*	*Target Coverage (%)*			*Conformity Index*			*Heterogeneity Index*		
		3DCRT	*DCAT*	*IMRT*	*3DCRT*	*DCAT*	*IMRT*	*3DCRT*	*DCAT*	*IMRT*
1	2	92.3 ±2.8	94.2 ± 1.8	97.5 ± 1.5	1.7 ± 0.5	1.8 ±0.5	2.0± 0.5	1.5± 0.2	1.3± 0.2	1.0± 0.2
2	17	90.7± 2.5	93.8 ± 1.5	95.7 ± 1	1.5 ± 0.5	1.6 ± 0.5	1.9 ± 0.5	1.1± 0.3	1.1±0.3	1.0± 0.2
3	2	90.3± 2.0	93± 1.0	95.2 ± 0.5	1.3± 0.01	1.4 ± 0.5	1.8±0.5	1.3 ±0.4	1.3±0.4	1.0± 0.2

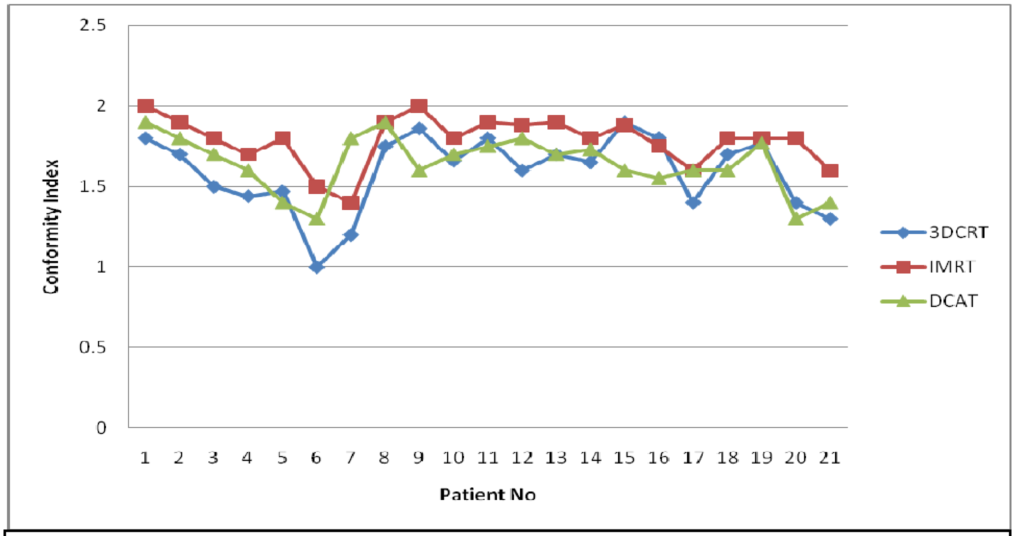

Figure 1: Conformity Index vs Patient Number

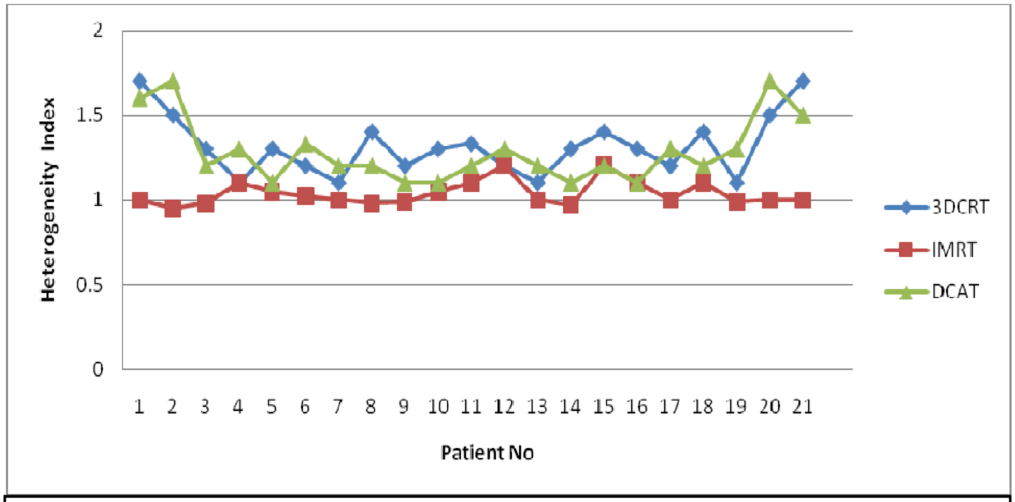

Figure 2: Heterogeneity Index vs Patient Number

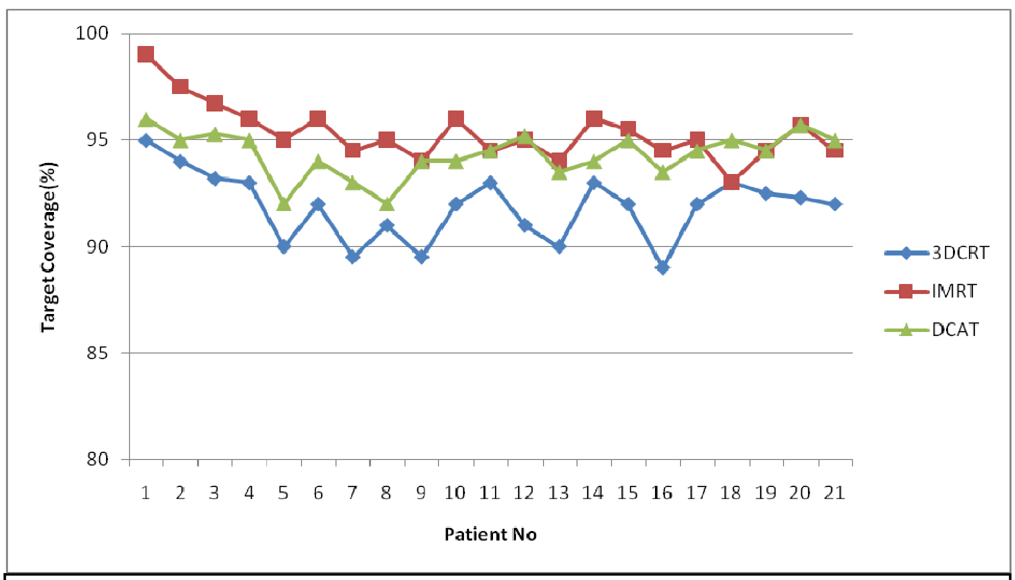

Figure 3: Target Coverage (%) vs Patient Number

tumor, the number of beamlets is limited. That means the number of solutions that satisfy the dosimetric constraints is also limited. As the number of beamlets increases, the number of solutions that meet the dosimetric requirements also increases. Thus, inverse planning can easily generate a good IMRT plan for a large target. Except for small tumors, IMRT is superior to 3D-CRT in the treatment of brain tumors, especially for those with irregular shapes and near some critical structures.

5. Conclusion

The results of our study have shown that DCAT is suitable for most cases in the treatment of brain tumors. For a small target, 3D-CRT is useful, and IMRT is not recommended. For larger tumors, IMRT is superior to 3D-CRT and very competitive in sparing critical structures near the target, especially for the treatment of a large brain tumor.

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