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■ 論 文 ■

Reduction of Patient Dose in Radiation Therapy for the Brain Tumors by Using 2-Dimensional Vertex or Oblique Vertex Beam Technique

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Abstract - Up-front irradiation technique as 3-dimensional conformation, or intensity modulation has kept large proportion of brain tumors from being complicated with acute radiation reactions in the normal tissue during or shortly after radiotherapy. For years, we've cannot help but counting on 2-D vertex beam technique to reduce acute reactions in the brain tumor patients because we're not equipped with 3-dimensional planning system. We analyzed its advantages and limitations in the clinical application. From 1998 to 2001, vertex or oblique vertex beams were applied to 35 patients with primary brain tumor and 25 among them were eligible for this analysis. Vertex(V) plans were optimized on the reconstructed coronal planes. As the control, we took the bilateral opposed techniques(BL) otherwise being applied. We compared the volumes included in 105% to 50% isodose lines of each plan. We also measured the radiation dose at various extracranial sites with TLD. With vertex techniques, we reduced the irradiated volumes of contralateral hemisphere and prevented middle ear effusion at contralateral side. But the low dose volume increased outside 100%; the ratio of V to BL in irradiated volume included in 100%, 80%, 50% was 0.55+/-0.10, 0.61+/-0.10, and 1.22+/-0.21, respectively. The hot area within 100% isodose line almost disappeared with vertex plan; the ratio of V to BL in irradiated volume included in 103%, 105%, 108% was 0.14+/-0.14, 0.05+/-0.17, 0.00, respectively. The dose distribution within 100% isodose line became more homogeneous; the ratio of volume included in 103% and 105% to 100% was 0.62+/-0.14 and 0.26+/-0.16 in BL whereas was 0.16+/-0.16 and 0.02+/-0.04 in V. With the vertex techniques, extracranial dose increased up to 1~3% of maximum dose in the head and neck region except submandibular area where dose ranged 1 to 21%. From this data, vertex beam technique was quite effective in reduction of unnecessary irradiation to the contralateral hemispheres, integral dose, obtaining dose homogeneity in the clinical target. But it was associated with volume increment of low dose area in the brain and irradiation toward the head and neck region otherwise being not irradiated at all. Thus, this 2-D vertex technique can be a useful quasi-conformal method before getting 3-D apparatus.

Key words : Vertex beam, Radiotherapy,

Introduction

Radiotherapy is very effective in control of most of the primary brain tumors because of limited role of the surgery. Only the small portion of tumors such as Grade I astrocytoma can be treated with surgical resection alone, and oftentimes the deep-seated tumors cannot be resected but permit minimal surgical procedures as stereotactic biopy, and sometimes surgery cannot be applied when the tumor is found in the vital site as the pons or medulla oblongata. (1,2)

Patients with many kinds of brain tumors as gliomas, meningiomas, pituitary adenomas, ependymomas, or more tumors have gained with substantially increased survival or median survival or even have reached natural life span. What is more, some radiosensitive brain tumors as germinomas can be cured with radiotherapy alone. Thus radiotherapy has quite important role and efforts toward increasing its efficacy have been recently tried by combining with chemotherapeutic agents. (3,4)

Acute or subacute reactions as erythema, pigmentation, dry skin, itching, wet or desquamation, hair loss, middle ear effusion, focal or general brain edema with expression of anorexia, nausea, vomiting can be complicated during radiotherapy procedures of 2 to 7 weeks or immediately after irradiation period. Some side effects can be complicated from 6 months after irradiation, among which endocrine, cognition, memory dysfunction is of concerned. (5)

These side effects are associated with daily dose(fraction size), total radiation dose, and irradiated volume, dose homogeneity, or individual radiosensitivity.

The radiation ports used for the conventional brain radiotherapy consisted of bilateral opposed beams with or without anterior beam in the neutral or flexed neck position. These techniques can be planned manually or easily with 2-dimensional computerized planning system.

This study aimed to reduce the irradiated volume or dose inhomogeneity by using vertex or oblique vertex beams instead of conventional beam techniques while maintaining the daily dose, total dose, or fractionation schedules. We are going to propose practical guidelines in using these techniques by collecting basic data and by analysis of its practical benefit, limitation in delivery, indicated primary site.

Material and Methods

From 1998 to 2001, vertex or oblique vertex beams were applied to 35 patients with primary brain tumor and 25 among them were eligible for this analysis.

Patients were immobilized with a thermoplastic mask and its supports in supine position and get CT scan with three position marks at the both lateral and anterior and slice thickness of CT image was 5 mm in average. The hardcopy of the image was put into a computerized radiotherapy planning system (Multidata, USA) via camera accessory. Tumor volume, CTV, and PTV were determined, and contours of the skin, both eyeball and lens, midbrain/pons/medulla was outlined. Initial obliquity of the vertex(V) beam was determined by beams-eye-view. Final radiotherapy plans were optimized on the reconstructed coronal plane using a lateral or both lateral beams at the center CT image. A linac(2100C, Varian, USA) was used for beam delivery.

Second optimization or modification was undertaken after filming lateral simulation. As the control, we took the bilateral opposed techniques(BL) which would be taken to the patients if vertex technique was not applied.

We compared the volumes included in 105% to 50% isodose lines of each plan. We also measured the radiation dose at various extracranial sites with TLD chips (7.5% Li-6 with 92.5% Li-7; TLD-100, Harshaw/Filtrol, USA). Side effects were also analyzed.

Table 1. Ratio of the area included in 103%, 105%, 108% isdose lines by Bilateral (L) techniques to Vertex(V) technique, respective

	Case	103%-V	103%-L	103% V/L	105%-V	105%-L	105% V/L	108%-V	108%-L	108% V/L
	8	8.87	57.33	0.155	0	21.91	0.000	0	0.01	0.000
	9	32.51	76.13	0.427	7.99	40.49	0.197	0	4.88	0.000
	10	9.59	52.75	0.182	0	4.84	0.000	0	0.01	0.000
	11	3.51	42.66	0.082	0	15.11	0.000	0	0.01	0.000
	13	2.84	46.67	0.061	0	21.54	0.000	0	0.01	0.000
	15	2.09	29.55	0.071	0	5.68	0.000	0	0.01	0.000
	16	4.9	33.05	0.148	0	17.87	0.000	0	1.94	0.000
	17	4.62	45.03	0.103	0	10.99	0.000	0	0.01	0.000
	18	4.52	33.85	0.134	0	4.44	0.000	0	0.01	0.000
	19	29.14	94.33	0.309	4.02	63.15	0.064	0	9.89	0.000
	20	5.15	53.36	0.097	0	23.51	0.000	0	0.01	0.000
	21	4.17	49.06	0.085	0	1.58	0.000	0	0.01	0.000
	22	4.94	26.23	0.188	0	7.79	0.000	0	0.01	0.000
	23	29.57	66.84	0.442	4.93	40.06	0.123	0	14.69	0.000
	24	0	35.07	0.000	0	14.7	0.000	0	0.01	0.000
	25	2.23	44.12	0.051	0	22.99	0.000	0	3.21	0.000
	26	0	47	0.000	0	5.87	0.000	0	0.01	0.000
	27	1.83	64.01	0.029	0	39.01	0.000	0	0.01	0.000
	28	4.38	77.28	0.057	0	55.34	0.000	0	4.29	0.000
	29	17.18	109.81	0.156	0.65	51.53	0.013	0	2.01	0.000
	30	32.2	61.19	0.526	13.81	16.99	0.813	0	0.01	0.000
	31	11.23	86.53	0.130	0.46	31.01	0.015	0	0.01	0.000
	32	1.05	51.71	0.020	0	23.04	0.000	0	0.01	0.000
	33	3.81	82.06	0.046	0	51.54	0.000	0	10.26	0.000
	34	1.63	22.6	0.072	0	1.42	0.000	0	0.01	0.000
sum				3.570			1.224			0.000
mean				0.143			0.049			0.000
SD				0.140			0.166			0.000

Table 2. Radiation dose to the extracranial regions measured by TLD chips during vertex or oblique vertex beam techniques for the primary brain tumors

Extracranial Region	Orthogonal vertex		Oblique vertex	
	Absolute dose (cGy)	Relative dose (%)	Absolute dose (cGy)	Relative dose (%)
Upper eyelid, Left	4.3	2.4	3.84	2.11
Right	4.0	2.3	5.50	3.06
Submandible Left	7.3	4.1	3.23	1.79
Right	22.7	12.6	18.18	10.10
Thyroid, Left	31.3	17.4	2.44	1.35
Right	34.2	19.0	3.11	1.73
Submental	8.4	4.7	2.23	1.24
Sternum Middle	3.0	1.7	0.95	0.53
Abdomen, Periumbilical	0.5	0.3	0.27	0.15
Perineum	0.3	0.1	0.13	0.07

Results

1. Practical advantage

With the vertex techniques, we broadened the usefulness of CT image data by using a coronal plane, we can increased the planned radiation dose by getting rid of dose limitation by pons or medulla, excluded the contralateral hemisphere, or middle ear from the plan.

The most advantageous tumor location was the temporal lobe and was followed by the parietal lobe. This technique was of little benefit to the occipital or frontal lobe tumors and was not useful for the deep-seated tumors or cerebellar tumors.

We also kept for the CTV maintaining the margin of 2 to 3 cm from the GTV. All the cases received radiotherapy as planned. (Fig-1, panel A & B)

2. Dose distribution

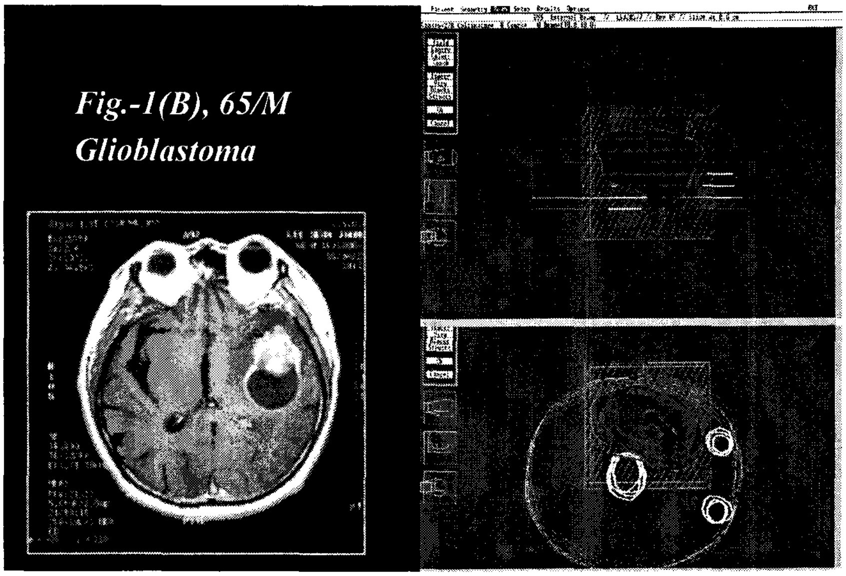
With vertex techniques, we reduced the irradiated volumes of contralateral hemisphere and prevented middle ear effusion at contralateral side. But the low dose volume increased outside 100%.

The ratio of V to BL in irradiated volume included in 100%, 80%, 50% was 0.55+/-0.10, 0.61+/-0.10, and 1.22+/-0.21, respectively. The hot area within 100% isodose line almost disappeared with vertex plan; the ratio of V to BL in irradiated volume included in 103%, 105%, 108% was 0.14+/-0.14, 0.05+/-0.17, 0.00, respectively. The dose distribution within 100% isodose line became more homogeneous; the ratio of volume included in 103% and 105% to 100% was 0.62+/-0.14 and 0.26+/-0.16 in BL whereas was 0.16+/-0.16 and 0.02+/-0.04 in V. (Table 1)

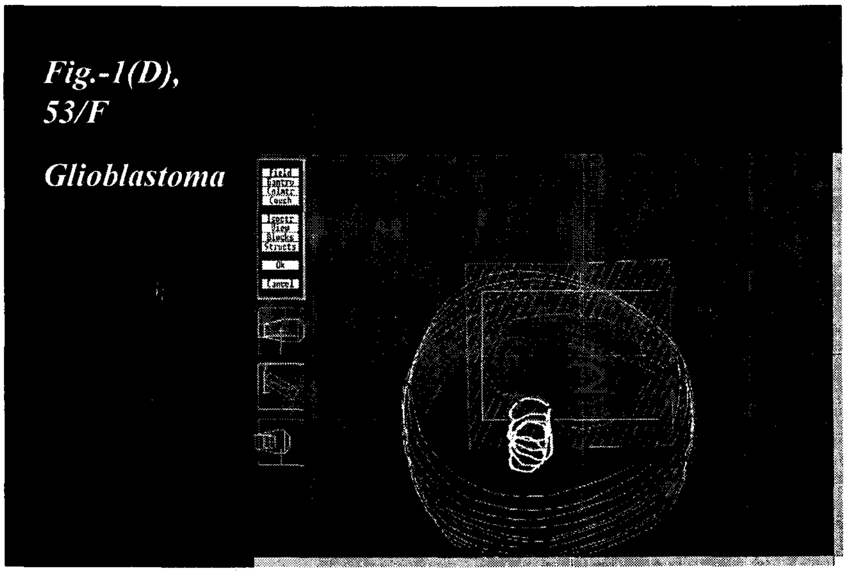
3. Extracranial dose and complication

With the vertex techniques, extracranial dose increased up to 1~3% of maximum dose in the head and neck region except submandibular area where dose was highest among the measure site and ranged 1 to 21% of the maximum dose of the respective plan. (Table 2)

Fig. 1. A) An MR image of a case with a glioblastoma at the left temporal lobe with a beams eye-view(BEV) of an orthogonal median vertex beam plan. The blue line encompasses the planning target volume and so individualized shielding is coincided with the margin and so midbrain or pons can be excluded from the radiation port.



(B). A case of primary brain tumor at the left temporal lobe with a beams eye-view (BEV)of an oblique vertex beam plan with which we could shield a large portion of the pons and thus successfully prevented the underneath bosy from irradiation.



Discussion

We can confirmed the advantages of the vertex or oblique vertex beam technique for the primary brain tumors, that the integral dose decreased, dose homogeneity increased, part of the contralateral hemisphere was excluded from the irradiation volume.

But there were some innate problems in using the vertex beam techniques in the planning procedures or in daily treatment setting.

Firstly, practical application of this technique was determined by the tumor location. The vertex technique was so effective in the temporal lobe or median tumors that we can save most part of the contralateral temporal lobe, contralateral inner ear, and midbrain or pons.

But when the optimally located tumor was malignant, critical organ of low tolerance as pons or medulla kept from this technique delivering full radiation dose around 60 Gy. Two kind of options could be taken, in this situation, reduction of the total dose or achieving full dose while shielding pons, medulla, and interposed portion of tumor also. The limitation of dose delivery by pontomedullary presence always exists in conventional radiotherapy. When one believes in the former policy, then one decided to use bilateral ports with or without anterior ports with neck flexion rather than taking the vertex beam technique. It can be a matter of choice after taking into consideration of the age, performance, expected curability of patient.

Secondly, practical application of this technique was determined by the tumor size. We think that the technique should not applied to a large tumor from the beginning but that could be used at the time of field reduction around 36 Gy. In case of large tumors, saved proportion in the contralateral hemisphere decreased and absorbed dose to the skull base or ipsilateral head increased.

Thirdly, we cannot take direct linac-gram of the oblique vertex port because we rotated a gantry and changed the couch angle simultaneously. Similar problem was reported by others. (6) Thus we used an indirect way of taking linac-gram of AP and lateral direction for ascertaining reproduction of the initial position or immobilization during radiotherapy period.

Alternative way of vertex beam technique can be adapted to check linac-gram directly. (7, 8) The neck of patient was hyperflexed in prone position. But this proposed technique also had two major shortcomings, firstly, decreased reliability of reproduction of treatment position because patient was not rigidly immobilized at all and secondly, patient was also unnecessarily irradiated at the pharynx, palate, tongue base, or other head and neck regions.

Fourthly, oblique beam techniques were always complicated with radiation exposure to the extracranial regions.

The median vertex beam, with couch rotation of 90 degree and gantry position at 270 degree, transited the body center and exited at perineum. This kind of phenomenon can be found in a certain arcplanes planned for linac-based radiosurgery

Thus we preferred oblique vertex beams, with couch rotation less than 90 degree and gantry position at 270 degree, to avoid exposure to the central body axis. But this angular modification of beam obliqueness has some problems, too. Although it was dependent on the obliqueness, lateral part of the head and neck or upper trunk still had radiation exposures.

It is noteworthy that we definitely reduced the irradiated brain volume included in 100% isodose line and also improved dose homogeneity within 100% isodose lines but at the same time the volume outside 100% isodose line - low dose area - also increased. Moreover, with this vertex beam technique the head and neck regions were also irradiated, which was never experienced with the bilateral opposed beam technique. It should be cautiously evaluated whether this trade-off would result in long-term benefit, no benefit, or worse.

From this data, vertex beam technique was quite effective in reduction of unnecessary irradiation to the contralateral hemispheres, integral dose, obtaining dose homogeneity in the clinical target. But it was associated with volume increment of low dose area in the brain and irradiation toward the head and neck region otherwise being not irradiated at all. Thus, this 2-D vertex technique can be a poor mans quasi-conformal method before getting 3-D apparatus.

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