TomoTherapy® Clinical Flexibility

The TomoTherapy® Hi·Art® treatment system's sophisticated delivery method allows tremendous planning flexibility and lessens the need for planning trade-offs between target coverage and critical structure avoidance.

BACKGROUND

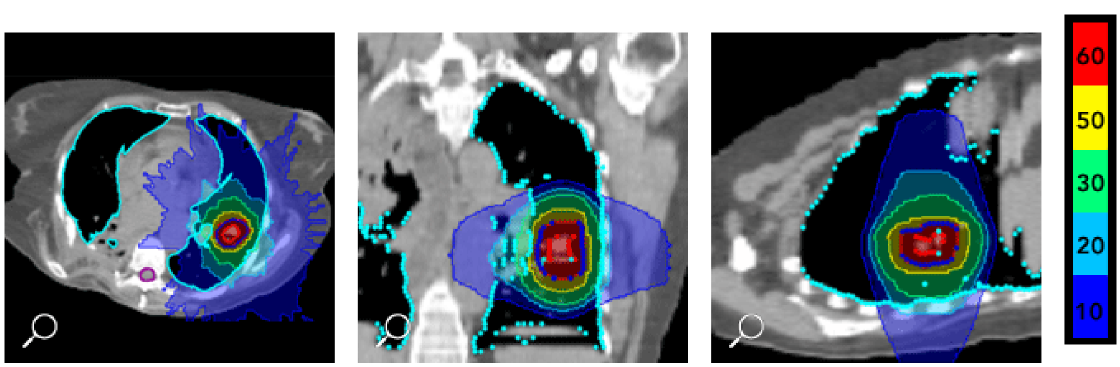
For any given case, there is no single plan that defines the capability of TomoTherapy®. Depending on the relative priorities given to achieving certain clinical goals, dosimetric planning results can differ.

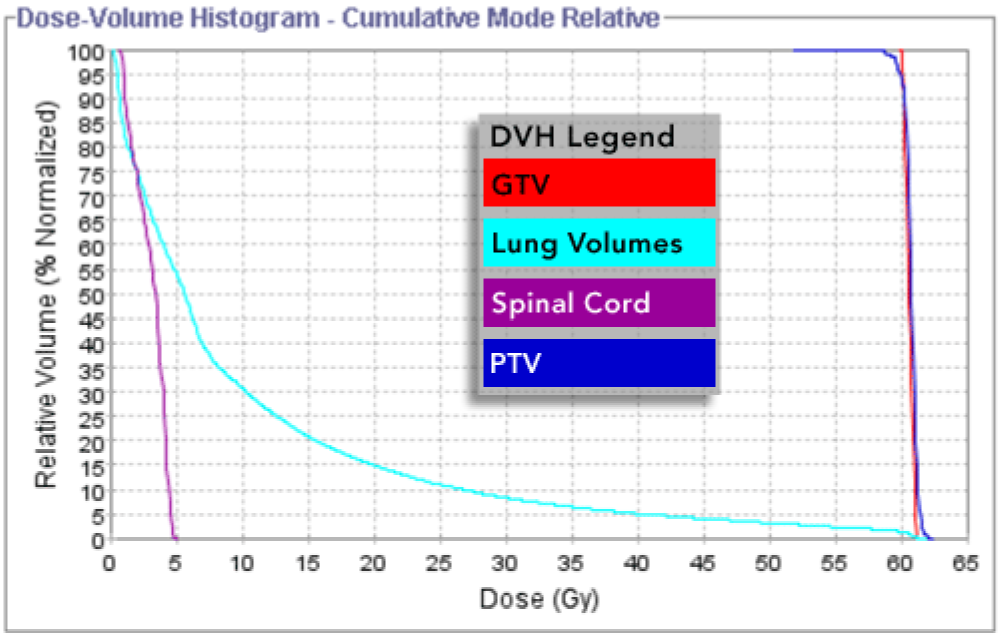
Three clinical cases were included in an article in the September 2007 edition of the **International Journal Radiation Oncology · Biology · Physics** (Volume 69, No. 1, pp. 240–250). The intent of the article was to compare intensity modulated arc therapy (IMAT) and helical TomoTherapy^{SM} treatments. TomoTherapy Incorporated obtained the original case files from one of the paper's authors and below demonstrates the fact that—for any given case—there is no single plan that defines the capabilities of *TomoTherapy*. Depending on the relative priorities given to achieving certain clinical goals, dosimetric planning results can differ significantly.

SBRT LUNG CASE

Original Plan

Planning was performed for a small left lung tumor (20.4 cm^3 PTV) to be treated with 60 Gy in three fractions. This is regarded as a stereotactic body radiotherapy (SBRT) treatment due to the high dose per fraction. The original plan called for 95% of the PTV to be covered by the prescription dose. The planner chose to maintain a uniform dose within the PTV by making this a high priority during plan optimization. The GTV, being within the PTV, naturally receives an even more uniform dose and a higher mean dose. Critical structures to be spared include both lungs and the spinal cord.



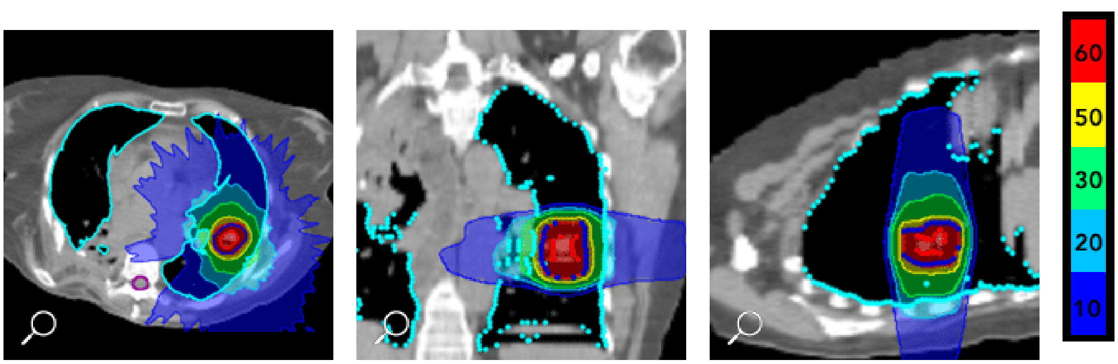


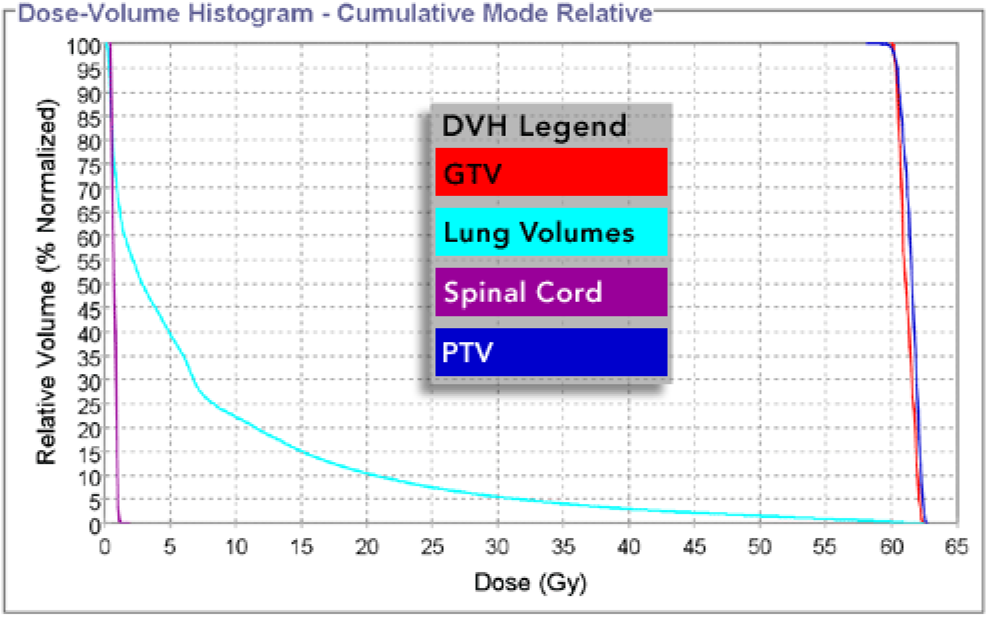
- PTV: Min/Max dose = 58/62 Gy
- Lungs: Mean dose = 10.4 Gy; V20Gy = 14.8%
- Cord: Max dose = 4.7 Gy

PTV dose is very uniform (dose spread only 4 Gy), at some expense to the degree of lung and cord sparing. This plan used a 2.5 cm collimator width, rather than a 1 cm width as used for the first revised plan below.

SBRT LUNG CASE - PLAN REVISION 1

For this plan a 1 cm collimator width was used to maximize the ability of the system to achieve a uniform PTV dose while achieving a very high degree of organ at risk sparing. In particular, the smaller collimator width increases the dose gradient superiorly and inferiorly to the PTV. As is shown here, target dose coverage and uniformity is maintained, or even slightly improved, over the original plan but with lower mean lung and maximum cord doses.



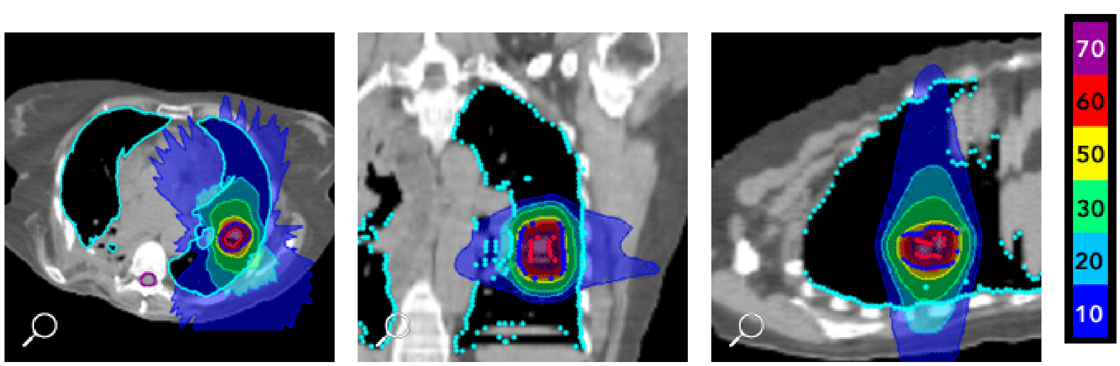


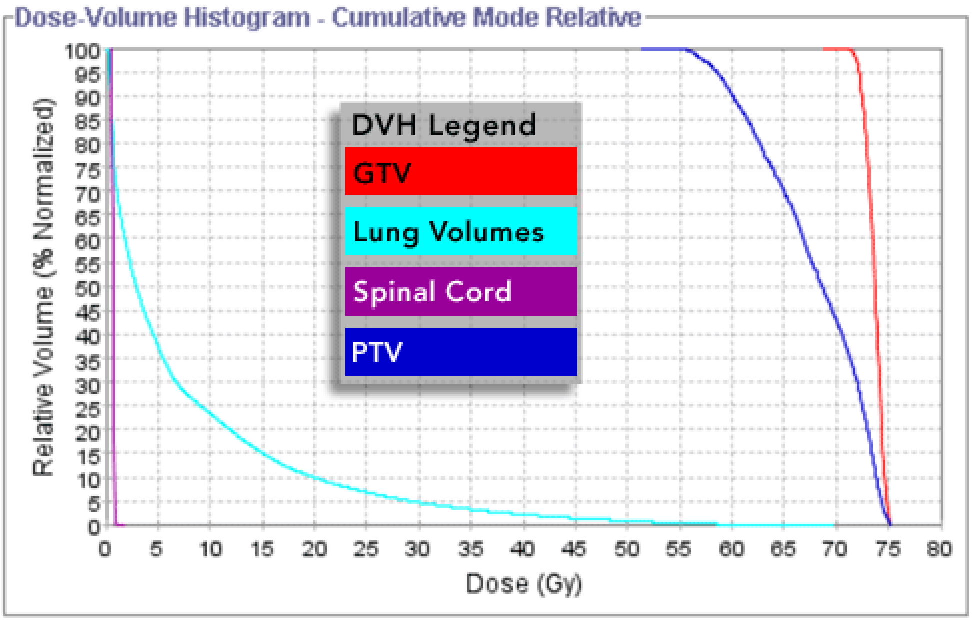
- PTV: Min/Max dose = 60/63 Gy
- Lungs: Mean dose = 7.4 Gy; V20Gy = 10.4%
- Cord: Max dose = 1.3 Gy

This plan achieved a fast dose falloff outside the PTV while maintaining a uniform dose inside the PTV. An alternative technique for creating a fast dose falloff is to relax the priority of achieving target dose uniformity, as demonstrated by the second revised plan below.

SBRT LUNG CASE - PLAN REVISION 2

Increasing the priority for lung sparing relative to PTV dose uniformity creates a faster dose gradient in the lung. This plan uses a 2.5 cm collimator yet achieves slightly better lung and cord sparing than with the 1 cm collimator plan above. The tradeoff is target dose uniformity, but since the intent of an SBRT treatment is target ablation there is good clinical rationale for allowing dose near the center of the PTV to be considerably higher than the minimum dose.





- PTV: Min/Max dose = 56/75 Gy
- Lungs: Mean dose = 7.2 Gy; V20Gy = 9.8%
- Cord: Max dose = 1.2 Gy

A very rapid dose falloff was achieved in this plan via maximum PTV dose being allowed to rise to 125% of the prescription dose. This takes advantage of the fact that dose gradients are greater at dose levels well below the maximum dose. Such an effect can be created in a TomoTherapy^{SM} treatment without the use of a smaller collimator. This TomoTherapy^{SM} plan achieves significantly better lung and cord sparing than the IMAT plan.

SBRT LUNG CASE - SUMMARY OF ORGAN SPARING RESULTS

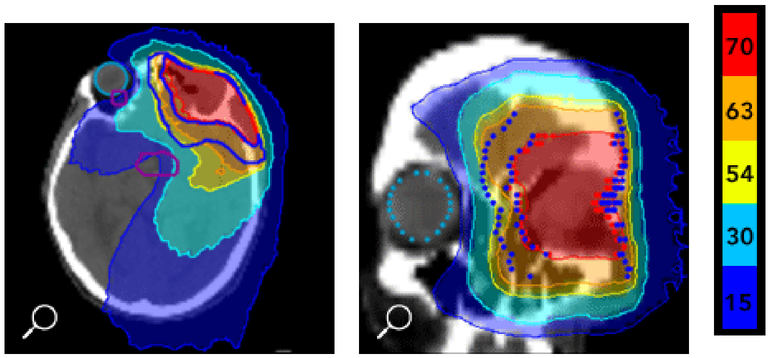
	IMAT	Tomo^{SM} original	*Tomo* rev 1	*Tomo* rev 2
Mean lung dose (Gy)	9.3	10.4 (12)	7.4 (-20)	7.2 (-23)
Max cord dose (Gy)	4.7	4.7 (0)	1.3 (-72)	1.2 (-74)

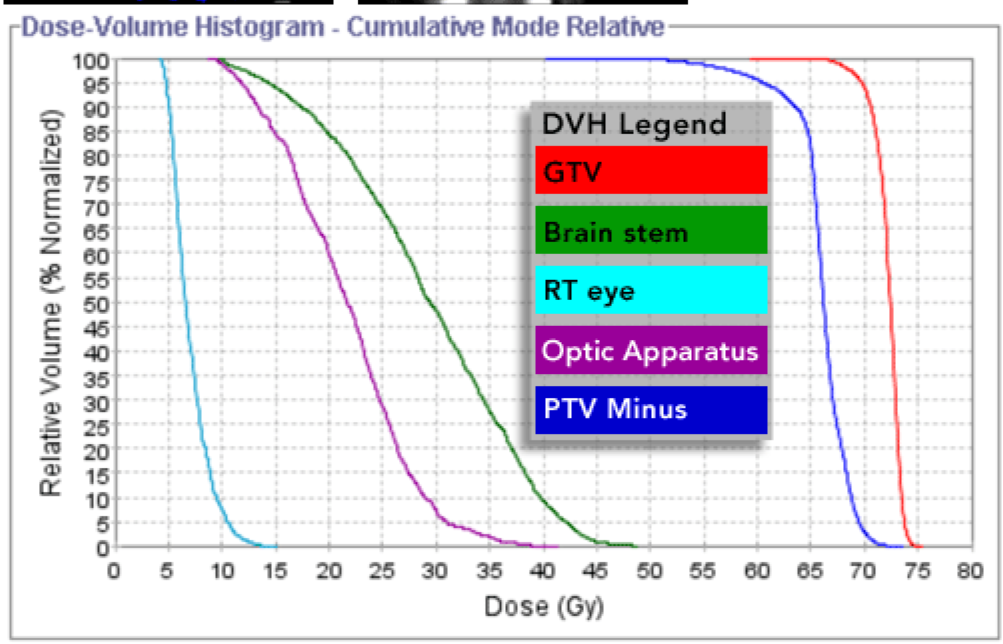
Mean lung and maximum cord doses for the original IMAT plan, original *TomoTherapy* plan, and revised *TomoTherapy* plans. For the *TomoTherapy* plans, percent differences compared to the IMAT plan are shown in parentheses.

LEFT ORBIT CASE

Original Plan
For this case, a volume including the left orbit forms the GTV, to which the prescription dose is 70 Gy. The IMAT plan used four sagittal arcs (couch angle 90 degrees) in order to better spare

the right eye, brain stem and optic apparatus than if axial arcs (couch angle 0 degrees) were used. This is an obvious strategy of trying to keep incoming beam paths away from these structures. The *TomoTherapy* system uses axial, helical gantry rotations but has the advantage of a very high modulation capability. In the original plan comparison, similar target dose coverage was achieved with the two techniques, but the IMAT plan achieved better critical structure sparing due to the use of sagittal arcs.



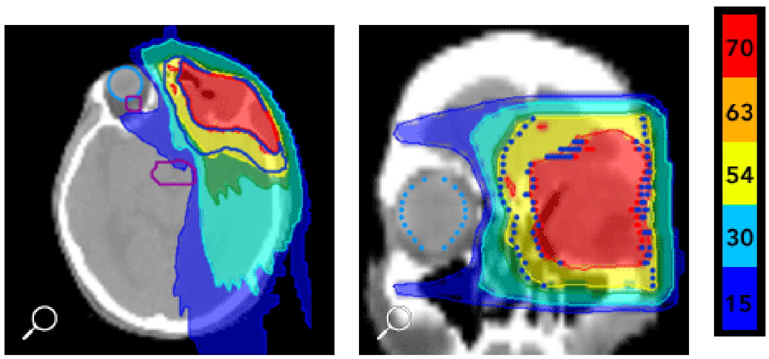


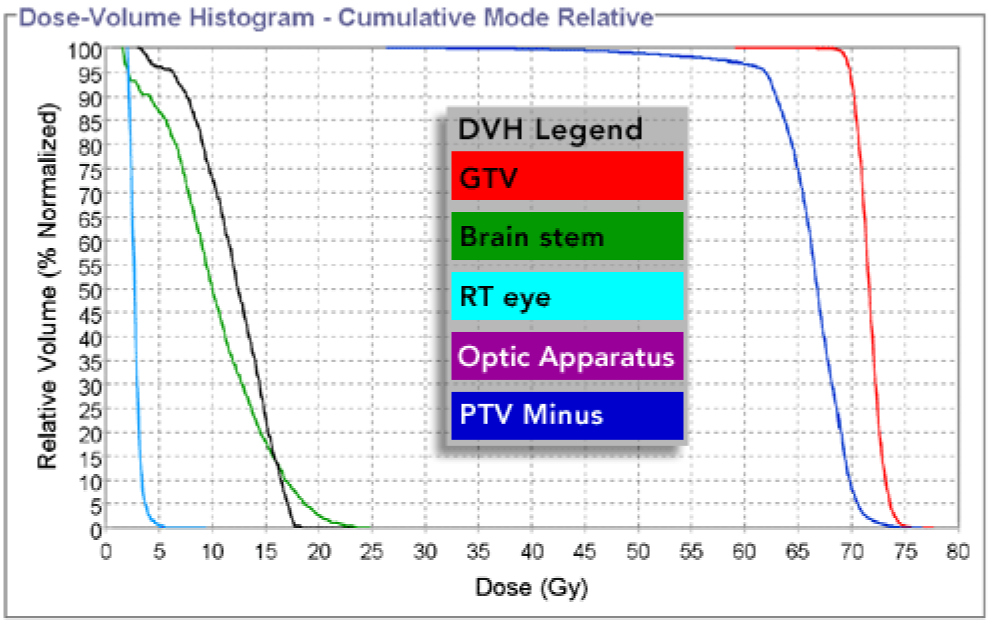
- GTV: Min/Max dose = 67/75 Gy
- Right eye: Mean/Max dose = 7.1/13.1 Gy
- Optic apparatus: Mean/Max dose = 21.7/38 Gy
- Brain stem: Max dose = 46.7 Gy

The *TomoTherapy* plan can be improved by setting more aggressive critical tissue constraints and making use of higher beam modulation.

LEFT ORBIT CASE - PLAN REVISION

Placing more aggressive dose constraints on critical structures, results in dramatically reduced maximum dose levels. The modulation factor was also increased, enabling the optimization algorithm to conform dose to the target volume more effectively.





- GTV: Min/Max dose = 68/75 Gy
- Right eye: Mean/Max dose = 2.8/5.5 Gy
- Optic apparatus: Mean/Max dose = 12.2/18 Gy
- Brain stem: Max dose = 23.5 Gy
- Note: No primary dose in oral cavity, in contrast to the IMAT plan

In this revised plan, the TomoTherapy® optimizer was able to create a plan with axial arcs that has significantly improved critical organ sparing compared to that achieved with non-axial arcs in the IMAT plan. The key enabler for this is the very high degree of modulation available.

LEFT ORBIT CASE - SUMMARY OF ORGAN SPARING RESULTS

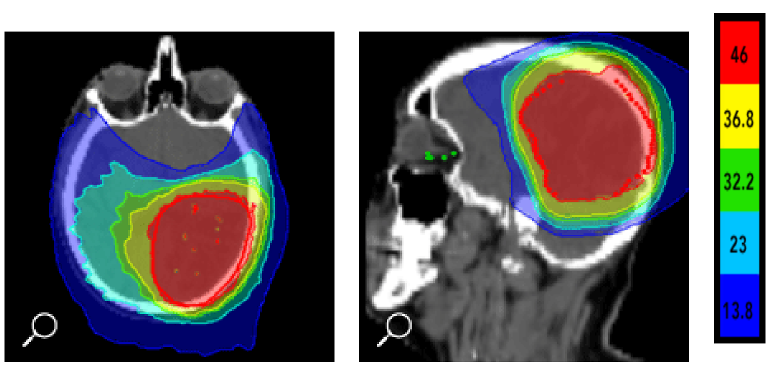
	IMAT	*Tomo* original	*Tomo* revised
Mean Rt eye dose (Gy)	3.4	7.1 (109)	2.8 (-18)
Max Rt eye dose (Gy)	10.9	13.1 (20)	5.5 (-50)
Mean optic apparatus dose (Gy)	15	21.7 (45)	12.2 (-19)
Max optic apparatus dose (Gy)	28.5	38 (33)	18 (-37)

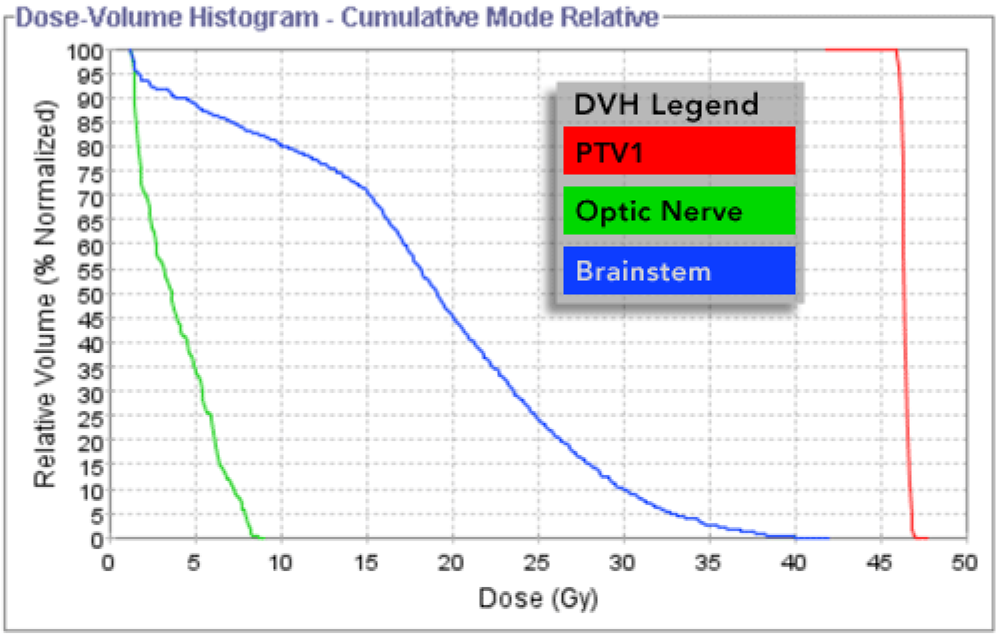
Mean and maximum doses for the right eye and optic apparatus for the original IMAT plan, original *TomoTherapy* plan, and the revised *TomoTherapy* plan. For the *TomoTherapy* plans, percent differences compared to the IMAT plan are shown in parentheses.

POSTERIOR BRAIN CASE

Original Plan

Plans for a *glioblastoma multiforme* in the left posterior part of the brain were generated using IMAT and *TomoTherapy*. Prescription dose was 46 Gy. The IMAT plan included four non-axial couch angles, each with four overlapping arcs (16 arcs in total). The rationale for this significant increase in plan complexity was again better critical structure sparing, in particular brain stem, optic nerve and both eyes. In the original plan comparison, critical structure sparing was better with IMAT, but at the expense of target dose uniformity.



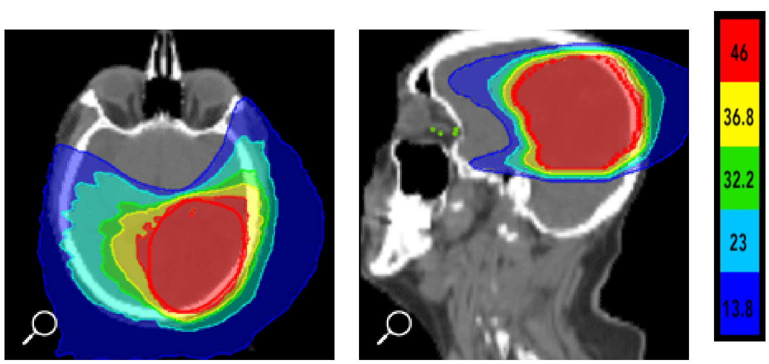


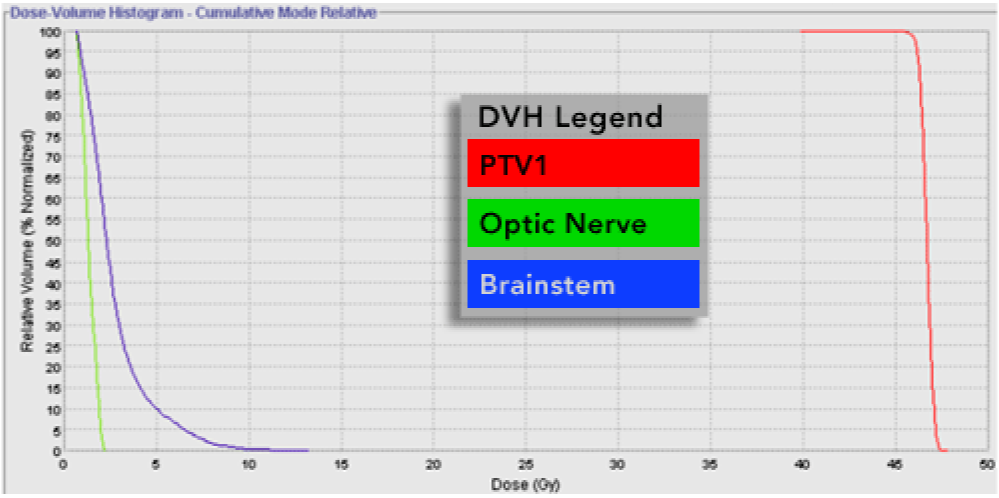
- PTV: Min/Max dose = 46/47 Gy
- Brain stem: Mean/Max dose = 18.7/39 Gy
- Optic nerve: Mean/Max dose = 3.9/8.1 Gy

As with the other case examples, the *TomoTherapy* system was able to achieve much better critical structure sparing with more aggressive optimization parameters and increased modulation.

POSTERIOR BRAIN CASE - PLAN REVISION

Brain stem and optic nerve sparing are both greatly improved with this revised plan. PTV coverage and dose uniformity are not compromised in this case.





- PTV: Min/Max dose = 46/47 Gy
- Brain stem: Mean/Max dose = 2.8/11 Gy
- Optic nerve: Mean/Max dose = 1.4/2.2 Gy

The revised TomoTherapy^{SM} plan achieves much better brain stem sparing and similar optic nerve sparing compared with the IMAT plan, without sacrificing target dose uniformity.

POSTERIOR BRAIN CASE - SUMMARY OF ORGAN SPARING RESULTS

	IMAT	*Tomo* original	*Tomo* revised
Mean brain stem dose (Gy)	6.1	18.7 (207)	2.8 (-54)
Max brain stem dose (Gy)	29.2	39 (34)	11 (-62)
Mean optic nerve dose (Gy)	1.0	3.9 (290)	1.4 (40)
Max optic nerve dose (Gy)	2.4	8.2 (242)	2.2 (-8)

Mean and maximum doses for the brain stem and optic nerve, for the original IMAT plan, the original *TomoTherapy* plan, and the revised *TomoTherapy* plan. For the *TomoTherapy* plans, percent differences compared to the IMAT plan are shown in parentheses.

The three original *TomoTherapy* plans presented above were originally included in an article in the September 2007 edition of the **International Journal Radiation Oncology · Biology · Physics** (Volume 69, No. 1, pp. 240–250).