Treatment planning for patients with resected GBM: Is post-operative MRI enough?

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Background

o In IMRT treatment planning for gliomas, target and normal tissue definition is commonly based on MR images registered to CT simulation images because of the superior visualization of brain tissues on MRI.

o However, due to the increased cost and time required for MR imaging, post-operative imaging is often used as the reference image rather than a dedicated MR-simulation image.

o Both the time between the acquisition of post-operative imaging – in which the tissue is recovering from surgery – and the quality of post-operative images – which are often have a larger slice-thickness than the simulation CT – can influence the accuracy of target and normal structure contours.

o To our knowledge, **there is no evidence to determine whether these effects are significant enough to justify the financial and time investment of an additional MRI at the time of simulation for treatment planning.**

Methods and Materials

o This study is a retrospective analysis of 13 patients originally planned in RayStation 9B (RaySearch Laboratories, Stockholm, Sweden) for treatment with IMRT as part of a prospective trial. These patients received an **MRI simulation (MR-SIM) at the time of CT simulation (CT-SIM)** for treatment planning.

o **Post-operative T1 post contrast (MR-PO) images** were imported from the patient's clinical record. These included both images collected in-house and imported from outside institutions. MR-PO images were rigidly registered to CT-SIM images.

o Organs at risk (OARs) and target structures were contoured once with reference to the MR-PO, and once with reference to the MR-SIM. Both sets of structures were copied to the CT-SIM for dose calculation.

o **A new treatment plan was created and optimized based on the MR-PO organs at risk and targets.** The target coverage and dose to organs at risk were evaluated for the MR-PO (used for optimization) and MR-SIM (actual geometry at treatment) structure sets.
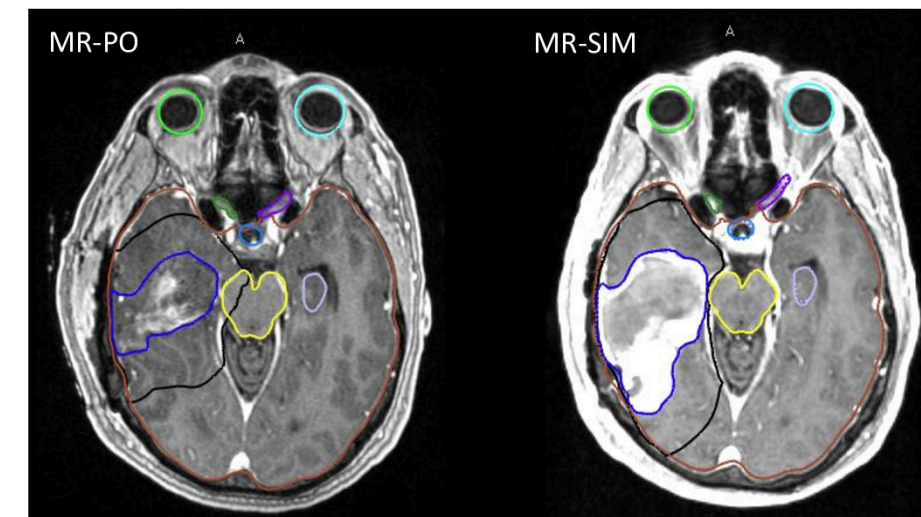

MR-PO   MR-SIM

Figure 1. GTV, CTV, brainstem, hippocampus, optic nerves, brain, pituitary, and eyes contoured on the post-operative MRI (MR-PO, left) and MR-Simulation (MR-SIM, right). Dramatic differences are noted in the volume of the GTV between the MR-PO (39.7cc) and the MR-SIM (59.7cc)

Results

Volume of over- and under-treated tissue

The volume of tissue that would have been over- or under-treated had the plan been based on the post-op MRI was evaluated. The mean (range) undertreated volume was 8.4cc (0.04cc to 27.9cc) for the GTV and 46.2cc (2.3cc to 179.1cc) for the CTV. The mean (range) overtreated volume was 7.5cc (0.3cc to 17.0cc) for the GTV and 28.9cc (0.3cc to 140.0cc) for the CTV.
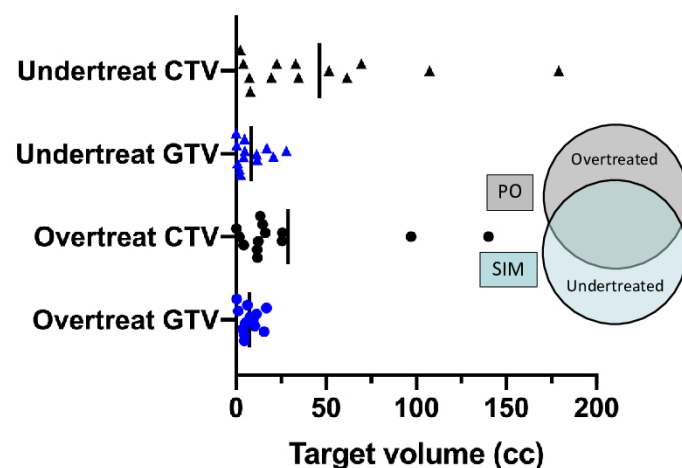

Figure 2. Summary of the overtreated and undertreated GTV and CTV volumes where overtreated volume = tissue included in the MR-PO target volume but not included in the MR-SIM target volume and undertreated volume = tissue contained in the MR-SIM target volume but not included in the MR-PO target volume.
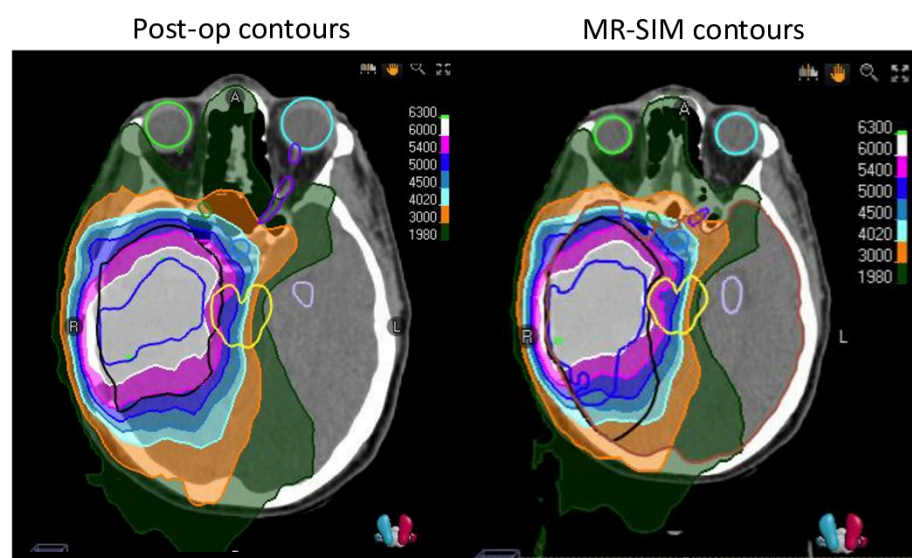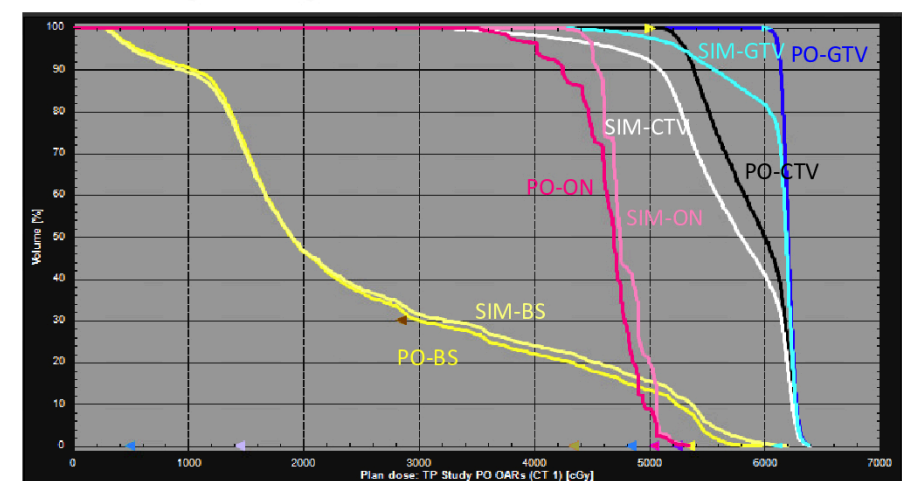

Post-op contours   MR-SIM contours

Figure 3. Top: Planned dose based on the MR-PO target structures and OARs. **Left:** PO-GTV and –CTV and PO-OARs. **Right:** SIM-GTV and –CTV and SIM-OARs. **Bottom:** DVH curves of the planned dose above, highlighting the decrease in target coverage and increase in dose to OARs.

	PTV50 50Gy Coverage (% target volume)			PTV60 60Gy Coverage (% target volume)		
Case #	TP	PO	Diff	TP	PO	Diff
1	79.3%	96.4%	-17.1%	69.4%	96.9%	-27.4%
2	99.9%	99.0%	0.9%	99.9%	98.3%	1.7%
3	95.5%	97.9%	-2.4%	95.3%	94.3%	1.0%
4	97.2%	99.3%	-2.1%	100.0%	99.4%	0.6%
5	99.7%	99.2%	0.5%	88.0%	97.1%	-9.0%
6	91.6%	99.2%	-7.6%	97.4%	95.8%	1.6%
7	78.1%	98.5%	-20.4%	99.6%	99.8%	-0.3%
8	92.8%	99.3%	-6.5%	98.8%	99.6%	-0.8%
9	66.7%	99.7%	-33.0%	99.5%	100.0%	-0.5%
10	99.2%	99.0%	0.2%	77.4%	87.6%	-10.2%
11	98.2%	98.4%	-0.2%	99.7%	99.9%	-0.2%
12	97.1%	98.9%	-1.7%	90.5%	95.5%	-5.0%
13	87.9%	99.8%	-11.9%	99.9%	99.3%	0.6%
Average	**91.0%**	**98.8%**	**-7.8%**	**93.5%**	**97.2%**	**-3.7%**

	Optic Chiasm Max Dose (cGy)			Brainstem Max Dose (cGy)		
Case #	TP	PO	Diff	TP	PO	Diff
1	5338.3	5359.3	-21.0	6208.3	5985.7	222.6
2	1311.2	1263.4	47.8	2174.7	2787.9	-613.2
3	5277.9	5256.8	21.1	6094.9	6011.7	83.2
4	4300.5	4721.6	-421.1	6012.7	5452.9	559.7
5	5313.0	5245.7	67.2	4430.5	3221.7	1208.8
6	6121.6	5400.4	721.2	6113.6	6113.6	0.0
7	4209.1	4361.7	-152.7	5488.0	5488.0	0.0
8	4780.3	4780.3	0.0	5819.3	5819.3	0.0
9	4776.4	4315.5	460.8	5774.7	5774.7	0.0
10	6311.5	5249.7	1061.8	6349.7	5997.7	352.0
11	2093.5	2263.0	-169.4	5022.6	5022.6	0.0
12	5925.2	5308.1	617.1	5996.3	5903.4	92.9
13	3427.4	2721.1	706.3	5325.5	5325.5	0.0
Average	**4552.7**	**4326.7**	**226.1**	**5447.0**	**5300.4**	**146.6**

Table 1. Target coverage (left) and dose to organs at risk (right) defined on the post-operative MRI (PO) and the MRI taken at the time of CT simulation (TP) for the plan developed based on the post-operative MRI for each of the 13 cases. Figures outside of typical clinical tolerances are highlighted in red.

Target coverage and dose to organs at risk

The tables above highlight key DVH metrics for the PTV50 and PTV60 (5mm expansions of the CTV and GTV, respectively), as well as the optic chiasm and brainstem. The target coverage fell from acceptable (>= 95%) to below the acceptable in 5 of 13 patients (38%) for PTV50 and 3 (23%) patients for PTV60. In 3 cases, dose to the optic chiasm and brainstem was acceptable (<54Gy and <60 Gy, respectively) when planned on the PO-MR, but exceeded tolerance when evaluated on the MR-SIM.

Conclusions

This preliminary study demonstrates the impact of using an immediate post-operative MRI for treatment planning compared with a dedicated MR simulation on dose coverage of the cavity and tumor at the time of simulation as well as differences in dose to organs at risk. Given the potential for anatomical changes between surgery and the time of simulation, these results support the value of a high-resolution treatment planning MRI at the time of CT simulation.