Figure 1 (a) Effective radiosensitivity maps of a selected slice of the primary gross tumor volume and (b) corresponding binary image (white: αeff>0; black: αeff<0)

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Correlation between MRI-based hyper-perfused areas and tumor recurrence in high-grade gliomas

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Purpose or Objective: Patients suffering from high-grade gliomas currently have a median survival time of 14 months despite treatment. Our purpose was to investigate whether MR perfusion and relative Cerebral Blood Volume (rCBV) maps could predict tumor recurrence areas and improve treatment planning.

Material and Methods: This retrospective study included 19 patients suffering from high grade gliomas (3 and 4) who received standard radiotherapy [60 Gy, 2 Gy/fraction] and Temodal chemotherapy. Subjects underwent pre-treatment CT, gadolinium-enhanced T1-weighted, T2 FLAIR acquisitions and a DSC-MR scan. rCBV maps were calculated using READE View Advantage Workstation (GE) and normalized to the normal white matter perfusion value. The PLANET software (DOSIsoft) was used to register all MR images to the planning CT. A senior radiologist and a senior radiotherapist delineated Gross Tumor Volumes (GTV) on anatomical MR images. The Planning Target Volumes (PTV) were defined by a physicist. Threshold of 1.7 was applied to the rCBV maps to define hyper-perfused volumes (Vperf). Follow-up anatomical MR images were used to localize recurrence areas (GTV'). Correlations between all volumes were analyzed using several indexes. I1 is the percentage of Vperf not included in the GTV. I2, I3, and I5 are respectively the percentage of GTV' included in Vperf, GTV, and PTV. I4 is the percentage of Vperf' not included in the GTV which was predictive of tumor recurrence outside GTV. This index is meaningful only if GTV' and GVT are different.

Results: Indexes obtained for each patient are presented in Table 1. For two patients, a threshold of 2 was applied to the rCBV maps at the physician request to facilitate the hyper-perfused area visualization. I1 values are in a range of 4 to 82% (mean = 43%) and are greater than 20% for almost 90% of the patients, indicating that hyper-perfused areas and GTV can be different. Hence, rCBV maps provide supplementary information. At least 40% of GTV' is included in Vperf for 16 patients (I2 index). For 10 patients, GTV' is not completely included in the GTV (I3 < 85%). In all these cases except one, the I4 index is greater than 20%, suggesting that a part of Vperf is predictive of the recurrence localization (Figure 1). I5 being almost always equal to 1 points out that all recurrence areas received the same dose as the GTV.

$$I1 = \frac{V_{Perf} - (V_{GTV} \cap V_{Perf})}{V_{Perf}} \quad I2 = \frac{V_{GTV'} \cap V_{Perf}}{V_{GTV'}} \quad I3 = \frac{V_{GTV'} \cap V_{GTV}}{V_{GTV'}}$$

$$I4 = \frac{(V_{GTV'} - V_{GTV}) \cap V_{Perf}}{V_{Perf} - V_{GTV}} \quad I5 = \frac{V_{GTV'} \cap V_{PTV}}{V_{GTV'}}$$

	I1	I2	I3	I4	I5
1	16	42**	80	59	100
2	63	7	38	33	100
3*	82	67**	35	28	100
4	60	54**	46	14	100
5*	47	47**	42	62	100
6	64	64**	46	47	100
7	4	59**	97	0	100
8	7	76**	99	2	100
9	32	66**	97	1	100
10	26	25	47	97	92
11	76	58**	97	0	100
12	46	45**	55	54	100
13	50	54**	48	48	100
14	25	61**	96	2	100
15	23	60**	86	4	99
16	17	44**	96	20	100
17	53	65**	89	1	100
18	32	38	77	39	100
19	15	46**	96	1	100

Table 1. Volume comparison indexes in 19 patients. The * sign indicates patients for whom a threshold of 2 was applied to rCBV maps at the request of the physicians. Yellow rows indicate patients for whom GTV' is not entirely included in GTV. The ** sign indicates patients for whom at least 40% of GTV' is included in Vperf.
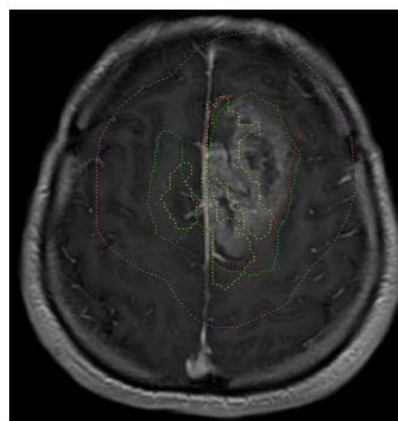

Figure 1. Volume comparison on pre-treatment gadolinium-enhanced T1-weighted for patient 1. A large part of GTV' (green) and Vperf (yellow) are included in GTV (red) in the left hemisphere. In the right hemisphere, the hyper-perfused area is predictive of tumour recurrence. GTV' is completely included in PTV (pink).

Conclusion: Our results suggest that rCBV perfusion maps can be predictive of recurrence localization. I1, I2 and I4 values are however entirely dependent on the threshold applied to rCBV maps and their evolution while the threshold increases will be studied. As recurrence areas are always included in the PTV, an improvement of treatment planning would consist in boosting hyper-perfused area rather than changing the GTV delineation. An in-depth analysis of the pre-treatment rCBV values observed in recurrence areas will be conducted to better describe potential boost areas.

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An image-based method to quantify biomechanical properties of the rectum in RT of prostate cancer

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