University of Michigan
Medical School

Advanced MR Imaging Protocol for Glioblastoma

Objective: Our goal is to develop and validate advanced MRI for identifying the most aggressive components of glioblastoma (GBM) for radiation boosting and for reliable therapy response assessment at multi-institutes.

Background: It is well known that post-Gd T1 weighted and FLAIR images underestimate and overestimate the tumor volume of GBM, respectively, and cannot assess therapy response reliably. In the last decade, physiological and metabolic imaging biomarkers (including both MRI and PET) have been developed for therapy assessment, and to a lesser extent for definition of treatment target of GBM.(1-16) Considering the wide availability, we focus on MRI techniques. Several MRI techniques have shown the predictive values for OS and PSF, including cerebral blood volume (CBV) (6-10), choline to N-acetylaspartate ratio (Cho/NAA) from 1H-MR spectroscopy imaging (1H-MRSI) (11-13), and functional diffusion map (fDM) derived from two time points of conventional diffusion-weighted (DW) imaging (with b-value $\leq$ 1000 s/mm^2) (4, 5). Recently, we developed an imaging technique for detection of hypercellular components of GBM using high b-value DW imaging by suppressing MR signals from edema and normal tissue.(3) We found that 1) the hypercellular volume (HCV) was a negative predictor for PSF, 2) the non-enhanced HCV could be treated inadequately due to poorer detection by conventional MRI, and 3) the mis-treated HCV resulted in rapid progression. These findings suggest that the HCV is an aggressive component of GBM, and could be targeted by intensified radiation doses or surgery to improve outcome. Also, this technique is easily deployed in a large scale clinical trial. Furthermore, biological heterogeneity of GBM indicates single imaging modality may not be sufficient to detect different image-phonotypes and assess heterogeneity response in GBM. Based upon these evidences, we develop the following MRI protocol for GBM.

MRI Protocol

A MRI protocol has been developed and evaluated on a 3T Siemens scanner in the University of Michigan and led by Dr. Yue Cao.

List of image series

1. Localizer
2. 3D T1-weighted images pre-contrast
3. 2D FALIR images
4. 2D multiple b-value diffusion weighted images
5. T1/B1 mapping
6. Dryrun for DCE

7. DCE series with contrast
8. 3D T1-weighted images post-contrast
9. DTI series

Acquisition Coil, Pulse Sequence and Parameters
Coil: Standard HN coil

1. Standard 3 orthogonal planes localizer

2. 3D T1-weighted images pre-contrast

Sequence type	MPRAGE	**TI (ms)**	900
3D or 2D	3D	**TE (ms)**	Min (2.4)
FOV (mm)	256x256x192	**TR (ms)**	1900
Voxel Size (mm)	1x1x1	**Flip angle (degree)**	9
Orientation	Sag*	**Parallel imaging factor**	2
# of slices	Whole brain	**Average**	1

*: can be reformatted to other orientations as physicians indicate.

3. 2D FALIR images

Sequence type	*tir2dl_16	**TI (ms)**	2370
3D or 2D	2D	**TE (ms)**	150
FOV (mm)	195x195x250	**TR (ms)**	8000
Voxel Size (mm)	1x1x3.9	**Average**	1
Orientation	Axial	**Parallel imaging factor**	2
Slice thickness and gap	3 mm with 30% gap	**#of slices**	Whole brain

4. 2D multiple b-value diffusion weighted images

Sequence type	Ep2d (*ep_b0)	**TE (ms)**	Min(98)
3D or 2D	2D	**TR (ms)**	8200
FOV (mm)	270x270x144	**Diffusion Gradient**	Bipolar*
Voxel Size (mm)	1.4x1.4x4.8	**3 orthogonal diffusion directions**	yes
Slice thickness and gap	4mm and 20%	**b-value (s/mm2)**	0, 1000, 2000 and 3000
Orientation	Axial	**Average**	1, 2, 3 and 4 for 4 b-values
# of slices	Whole brain	**Parallel**	4**

		imaging factor	

*: to reduce eddy current; **: to reduce geometric distortion

5. T1/B1 mapping

B1

Sequence type	tfl2dl-512	**TE (ms)**	Min(1.8)
3D or 2D	2D	**TR (ms)**	5050
FOV (mm)	260x260x210	**Flip angle (degree)**	8
Voxel Size (mm)	6x6x16	**Average**	1
Slice thickness and gap	8 mm with 100%		
Orientation	Sag		
# of slices	Whole brain		

*: we started the protocol without B1 mapping. By then, it was not available to us.

T1 mapping

Sequence type	3dgre (*fl3dl)	**TE (ms)**	Min(2.1)
3D or 2D	3D	**TR (ms)**	7
FOV (mm)	256x256x208	**Flip angle (degree)***	2, 5, 10, 15, and 30
Voxel Size (mm)	2x2x2	**Average**	1
Orientation	Sag	**Parallel imaging factor**	2
# of slices	Whole brain		

*: to reduce scanning time, three flip angles of 5, 10 and 30 can be used.

6. Dryrun for DCE: Parameters are identical to DCE series except it only runs 30-45 s. The purpose of it is to ensure the setup right before contrast injection.
7. DCE series with contrast

Sequence type	TWIST(*fldyn3dl)	**TE (ms)**	Min(~1)
3D or 2D	3D	**TR (ms)**	Min(~2.66)
FOV (mm)	260x260x160	**Flip angle (degree)**	10
Voxel Size (mm)	1.8x1.8x1.8	**# of dynamic phases**	60
Orientation	Sag	**Temporal resolution (s)**	~3
# of slices	Whole brain	**Average**	1
Parallel imaging factor		**Center region A/Sampling density B**	17%/20%

*: single dose of Gd-based contrast injected with a rate of 2cc/s followed by 20 cc saline after acquiring 5 dynamic volumes

8. 3D T1-weighted images post-contrast

Sequence type	MPRAGE	**TI (ms)**	900
3D or 2D	3D	**TE (ms)**	Min (2.4)
FOV (mm)	256x256x192	**TR (ms)**	1900
Voxel Size (mm)	1x1x1	**Flip angle (degree)**	9
Orientation	Sag*	**Parallel imaging factor**	2
# of slices	Whole brain	**Average**	1

*: can be reformatted to other orientations as physicians indicate.

9. DTI series

Sequence type	Ep2d (*ep_b0)	**TE (ms)**	Min(~95)
3D or 2D	2D	**TR (ms)**	Min(~4600)
FOV (mm)	220x220x140	**Diffusion Gradient**	bipolar
Voxel Size (mm)	1.8x1.8x3.9	**Directions of diffusion weighting**	20
Slice thickness and gap	3 mm with 30% gap	**b-value (s/mm2)**	0 and 1000
Orientation	Axial	**Average**	3
# of slices	Whole brain	**Parallel imaging factor**	2

Reference:

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