PBTC-045 MR Imaging Protocol

Brain MR with and without gadolinium will be obtained preferably on the 3T magnet consisting of:

- Sagittal T1 MPRAGE (slice thickness 1.0, 25 cm FOV)
- Axial T2 images (slice thickness 2mm skip 0, 20 cm FOV)
- Axial T2 FLAIR images (slice thickness 4mm skip 0, 20 cm FOV)
- Axial DTI images (slice thickness 2.0 mm skip 0, 22 cm FOV); 35 directions, bvalues: 0 and 1000 s/mm^2
- Axial SWI images (slice thickness 1.25 mm skip 0, 20 cm FOV)
- Axial T1 permeability(see below)
- Axial T2* perfusion(see below)
- Post gadolinium sagittal T1 SPACE (slice thickness 0.9 mm skip 0, 22 cm FOV)
- Axial T1 post gadolinium images through the whole brain (slice thickness 4mm skip 0, 20 cm FOV)
- MR spectroscopy(see below)

Brain MR with and without gadolinium on 1.5 T:

- Sagittal T1 (slice thickness 5 mm skip 1 mm, 22 cm FOV)
- Axial T2 images (slice thickness 4 mm skip 0 mm, 20 cm FOV)
- Axial T2 FLAIR images (slice thickness 5 mm skip 0 mm, 20 cm FOV)
- Axial DWI, 6 directions (slice thickness 5 mm skip 0 mm, 26 cm FOV)
- Axial MPGR (slice thickness 5 mm skip 0 mm, 20 cm FOV)
- Axial T1 permeability(see below)
- Axial T2* perfusion(see below)
- Post gadolinium sagittal 3DFSPGR images (slice thickness 1.5 mm no skip, 24 cm FOV)
- Axial T1 post gadolinium (slice thickness 3 mm no skip, 16 cm
- MR spectroscopy(see below)

Protocol for Spine

- Sagittal T1 images should be after gadolinium (slice thickness 3 mm skip 0).
- Axial T1 images are after gadolinium(slice thickness 3mm skip 0). Axial T2 images are optional

MRI Permeability and Perfusion Imaging:

The perfusion protocol will be performed using T1-weighted dynamic contrast-enhanced (DCE) permeability MRI to assess immediate biological activity followed by T2*-weighted dynamic susceptibility contrast (DSC) perfusion MRI technique. DSC perfusion MRI dynamics will allow assessment of the hemodynamic parameter relative cerebral blood volume (rCBV). DCE permeability MRI metrics will include the volume transfer constant between plasma and extravascular extracellular space (K^{trans}), fractional blood-plasma volume (V_p), and the volume of the extravascular extracellular space per unit volume tissue (V_e). Both DCE and DSC MRI-derived data will be complementary to conventional contrast-enhanced MR imaging.

DCE permeability MRI

Please note that there will be a total of 5 sequences: 4 for T1 mapping and the DCE with injection). A 3D (not 2D) fast gradient echo type of sequences (fast SPGR, FLASH, THRIVE) must be used. This will be performed as 3D slab in the axial plane. Normalization or intensity correction or flow correction filters such as CLEAR, SCIC or PURE must not be used for any of the series. The slice locations and positioning for the T_1 mapping and the dynamic series *MUST* be identical (same matrix, slices, FOV, TR, TE, except NEX and FA). Hence copying of the slices is needed. The TR and TE for all 4 series (4 T_1 maps plus a dynamic series) should be identical. For GE systems, reduce Turbo Factor to 1 or 0 if TR and TE do not match across series. T_1 Maps should be acquired with 2 signal averages and the Dynamic Series with 1. Temporal Resolution of "T1 DCE" series (scan time per phase/measurement) *should be less than or equal to 6 Seconds, with NO gaps between phases.* ASSET/IPAT/Parallel Imaging Parallel imaging is set to be OFF, however, if it is not possible to achieve a temporal resolution of less than 6 seconds, this should be set to a factor of 2. The dynamic series should last *5 minutes* in total scan time (*excluding* T1 mapping series).

The table below describes the image acquisition parameters for the T_1 map sequences as well as the dynamic scan, ***in the order of acquisition (first T1 maps then T1 DCE)***. Make sure this happens ***before*** DSC perfusion MRI.

The first half dose of contrast agent to be administered 20 sec into "T1 DCE" sequence. Do NOT inject prior to T1 DCE or during T1 maps (see tables 1 and 2 below).

Table 1: "T1 DCE"

Series Name	Sequence	Flip Angle	Notes
T1 map15	3D fast GRE	15 degrees	Axial, 2 NEX
T1 map10	3D fast GRE	10 degrees	Axial, 2 NEX
T1 map05	3D fast GRE	5 degrees	Axial, 2 NEX
T1 map02	3D fast GRE	2 degrees	Axial, 2 NEX
T1 DCE	Dynamic Series, 3D fast GRE	15 degrees	Axial, 1 NEX, inject 20 sec into this

Table 2:3D T1W specs for T_1 Maps and Dynamic Series	
Sequence type	Spoiled gradient echo
Imaging mode	**3D**
Slice orientation	Axial
Frequency direction	A/P
Phase direction	R/L
FOV - frequency	220 mm
FOV - phase	220 mm
Matrix - frequency	256
Matrix - phase	160-192
In-plane resolution	≤ 1 mm
Fat-suppression	No Fat Sat
TR	~4 msec
TE	Less than 2 ms or min full
TI (STIR sequence)	N/A
Flip Angle	DCE -15 degrees; T1 maps - 2, 5, 10 and 15
Slice thickness (acquired, not interpolated)	5mm, maximum 6mm
Number of slices	Minimum 10 prior to zero fill
Slice Gap	No gap
Parallel imaging factor	≤ 2
Number of averages	1 for DCE, 2 for T1 maps
k-space ordering	standard, non-centric
Temporal Resolution of "T1 DCE": (seconds per phase/measurement)	≤ 6 seconds
"T1 DCE" imaging duration	≥ 5 minutes

Run the Dynamic multi-phase "T1 DCE" at flip angle of 15 degrees – enable multi-phase (on GE systems) and increase the number of phases (or measurements) until the scan time is **six** minutes. Contrast injection should be delivered at 20 sec into T1 DCE, not earlier. Injection rate is 2 ml/second at 0.05 mmol/kg body weight followed by a 10 cc saline flush at the same rate (all should use the same type of contrast agent).

Diffusion tensor imaging

Diffusion tensor imaging (DTI) or axial T2 weighted imaging can be performed between the DCE and DSC MRI acquisitions. In addition to providing permeability metrics, the gadolinium contrast agent from the DCE acquisition will also serve as a "preload" to help correct for leakage effects for the DSC perfusion acquisition.

DSC perfusion MRI

An axial 2D T2* GRE-EPI sequence will be used. TR = 2000 ms, TE = 23 ms, matrix = 128 x 128, FOV = 240 mm, frequency direction R-L, slice thickness = 5.0 mm with 2 mm gap, flip angle = 60 degrees, NEX = 1. Repeat 50-60 times. Total acquisition time ~ 2 minutes. Begin bolus injection (2 ml/sec) of 0.05mmol/kg BW GdDTPA at 20secs after scanning starts followed by a 10 cc saline flush at the same rate. Regional rates of transverse relaxation enhancement ($\Delta R2^*$) during contrast agent passage will be calculated from: $\Delta R2^*(t) = (-1/TE) \ln [S(t)/S(0)]$ from which estimates of rCBV will be derived