TABLE 1: MINIMUM STANDARD 1.5T & 3T MRI PROTOCOL

	3D T1w Pre[b]	Ax 2D FLAIR[j]	Ax 2D DWI	Contrast Injection[a]	Ax 2D T2w[h,i]	3D T1w Post[b]
Sequence	IR-GRE[e,f]	TSE[c]	SS-EPI[g]		TSE[c]	IR-GRE[e,f]
Plane	Sagittal/ Axial	Axial	Axial		Axial	Sagittal/Axial
Mode	3D	2D	2D		2D	3D
TR [ms]	2100[m]	>6000	>5000		>2500	2100[m]
TE [ms]	Min	100-140	Min		80-120	Min
TI [ms]	1100[n]	2000-2500[k]				1100[n]
Flip Angle	10º-15º	90º/≥160º	90º/180º		90º/≥160º	10º-15º
Frequency	≥172	≥256	≥128		≥256	≥172
Phase	≥172	≥256	≥128		≥256	≥172
NEX	≥1	≥1	≥1		≥1	≥1
FOV	256mm	240mm	240mm		240mm	256mm
Slice Thickness	≤1.5mm	≤4mm[l]	≤4mm[l]		≤4mm[l]	≤1.5mm
Gap/Spacing	0	0	0		0	0
Diffusion Options[p]			b = 0, 500, 1000 s/mm^2 ≥3 directions			
Parallel Imaging	Up to 2x	Up to 2x	Up to 2x		Up to 2x	Up to 2x
Scan Time (Approx) [Benchmarked on 3T Skyra]	5-10 min [5:49 for 1mm isotropic]	4-8 min [3:22 for 2D FLAIR]	2-4 min [1:22 for 3 direction DWI and 3 b-values]		4-8 min [5:10 for dual echo]	5-10 min [5:49 for 1mm isotropic]

[a] 0.1 mmol/kg dose injection with a Gadolinium chelated contrast agent. Use of a power injector is desirable at an injection rate of 3-5cc/sec.

[b] Post-contrast 3D T1-weighted images should be collected with equivalent parameters to pre-contrast 3D T1-weighted images

[c] TSE = turbo spin echo (Siemens & Philips) is equivalent to FSE (fast spin echo; GE, Hitachi, Toshiba)

[d] FL2D = two-dimensional fast low angle shot (FLASH; Siemens) is equivalent to the spoil gradient recalled echo (SPGR; GE) or T1- fast field echo (FFE; Philips), fast field echo (FastFE; Toshiba), or the radiofrequency spoiled steady state acquisition rewound gradient echo (RSSG; Hitachi). A fast gradient echo sequence without inversion preparation is desired.

[e] IR-GRE = inversion-recovery gradient-recalled echo sequence is equivalent to MPRAGE = magnetization prepared rapid gradient-echo (Siemens & Hitachi) and the inversion recovery spoiled gradient-echo (IR-SPGR or Fast SPGR with inversion activated or BRAVO; GE), 3D turbo field echo (TFE; Philips), or 3D fast field echo (3D Fast FE; Toshiba).

[f] A 3D acquisition without inversion preparation will result in different contrast compared with MPRAGE or another IR-prepped 3D T1-weighted sequences and therefore should be avoided.

[g] In the event of significant patient motion, a radial acquisition scheme may be used (e.g. BLADE [Siemens], PROPELLER [GE], MultiVane [Philips], RADAR [Hitachi], or JET [Toshiba]); however, this acquisition scheme is can cause significant differences in ADC quantification and therefore should be used only if EPI is not an option. Further, this type of acquisition takes considerable more time.

[h] Dual echo PD/T2 TSE is optional for possible quantification of tissue T2.

[i] Advanced sequences can be substituted into this time slot, so long as 3D post-contrast T1-weighted images are collected between 4 and 8 min after contrast injection.

[j] 3D FLAIR is an optional alternative to 2D FLAIR, with sequence parameters as follows per EORTC guidelines: 3D TSE/FSE acquisition; TE=90-140ms; TR=6000-10000ms; TI=2000-2500ms (chosen based on vendor recommendations for optimized protocol and field strength); GRAPPA≤2; Fat Saturation; Slice thickness ≤ 1.5mm; Orientation Sagittal or Axial; FOV ≤ 250 mm x 250 mm; Matrix ≥ 244x244.

[k] Choice of TI should be chosen based on the magnetic field strength of the system (e.g. TI ≈ 2000ms for 1.5T and TI ≈ 2500ms for 3T).

[l] In order to ensure comparable SNR older 1.5T MR systems can use contiguous (no interslice gap) images with 5mm slice thickness or increase NEX for slice thickness ≤4mm.

[n] For Siemens and Hitachi scanners. GE, Philips, and Toshiba scanners should use a TI = 400-450ms for similar contrast.

[m] For Siemens and Hitachi scanners. GE, Philips, and Toshiba scanners should use a TR = 5-15ms for similar contrast.

[p] Older model MR scanners that are not capable of >2 b-values should use b = 0 and 1000 s/mm^2.

Acronyms:
Ax = Axial; ADC = apparent diffusion coefficient. FLAIR = fluid attenuated inversion recovery; DWI = diffusion-weighted imaging; 3D = three dimensional; TSE = turbo spin echo; EPI = echo planar imaging; SS-EPI = single-shot echo planar imaging; GE-EPI = gradient echo echo planar imaging; 2DFL = two-dimensional FLASH (fast low angle shot) gradient recalled echo; MPRAGE = magnetization prepared rapid gradient-echo; A/P = anterior to posterior; R/L = right to left; NEX = number of excitations or averages; FOV = field of view; TE = echo time; TR = repetition time; TI = inversion time; PD = proton density; DSC = dynamic susceptibility contrast; IR-GRE = inversion-recovery gradient-recalled echo

TABLE 2: RECOMMENDED 3T PROTOCOL

	3D T1w Pre	Ax 2D FLAIR	Ax 2D DWI	Contrast Injection [a]	Ax 2D T2w	3D T1w Post[b]
Sequence	IR-GRE[d,e]	TSE[c]	EPI[f]		TSE[c]	IR-GRE[d,e]
Plane	Sagittal/Axial	Axial	Axial		Axial	Axial/Sagittal
Mode	3D	2D	2D		2D	3D
TR [ms]	2100[g]	>6000	>5000		>2500	2100[g]
TE [ms]	Min	100-140	Min		80-120	Min
TI [ms]	1100[h]	2500				1100[h]
Flip Angle	10º-15º	90º/≥160º	90º/180º		90º/≥160º	10º-15º
Frequency	256	≥256	128		≥256	256
Phase	256	≥256	128		≥256	256
NEX	≥1	≥1	≥1		≥1	≥1
FOV	256mm	240mm	240mm		240mm	256mm
Slice Thickness	1mm	3mm	3mm		3mm	1mm
Gap/Spacing	0	0	0		0	0
Diffusion Options			b = 0, 500, and 1000 s/mm^2 ≥3 directions			
Parallel Imaging	Up to 2x	Up to 2x	Up to 2x		Up to 2x	Up to 2x
Scan Time (Approx)	5-8 min	4-5 min	3-5 min		3-5 min	5-8 min

[a] 0.1 mmol/kg or up to 20cc (single, full dose) of MR contrast.

[b] Post-contrast 3D axial T1-weighted images should be collected with identical parameters to pre-contrast 3D axial T1-weighted images

[c] TSE = turbo spin echo (Siemens & Philips) is equivalent to FSE (fast spin echo; GE, Hitachi, Toshiba)

[d] IR-GRE = inversion-recovery gradient-recalled echo sequence is equivalent to MPRAGE = magnetization prepared rapid gradient-echo (Siemens & Hitachi) and the inversion recovery spoiled gradient-echo (IR-SPGR or Fast SPGR with inversion activated or BRAVO; GE), 3D turbo field echo (TFE; Philips), or 3D fast field echo (3D Fast FE; Toshiba).

[e] A 3D acquisition without inversion preparation will result in different contrast compared with MPRAGE or another IR-prepped 3D T1-weighted sequences and therefore should be avoided.

[f] In the event of significant patient motion, a radial acquisition scheme may be used (e.g. BLADE [Siemens], PROPELLER [GE], MultiVane [Philips], RADAR [Hitachi], or JET [Toshiba]); however, this acquisition scheme is can cause significant differences in ADC quantification and therefore should be used only if EPI is not an option.

[g] For Siemens and Hitachi scanners. GE, Philips, and Toshiba scanners should use a TR = 5-15ms for similar contrast.

[h] For Siemens and Hitachi scanners. GE, Philips, and Toshiba scanners should use a TI = 400-450ms for similar contrast.

Acronyms:
Ax = Axial; ADC = apparent diffusion coefficient. FLAIR = fluid attenuated inversion recovery; DWI = diffusion-weighted imaging; 3D = three dimensional; TSE = turbo spin echo; EPI = echo planar imaging; MPRAGE = magnetization prepared rapid gradient-echo; A/P = anterior to posterior; R/L = right to left; NEX = number of excitations or averages; FOV = field of view; IR-GRE = inversion-recovery gradient-recalled echo

TABLE 3: RECOMMENDED 1.5T PROTOCOL

	3D T1w Pre	Ax 2D FLAIR	Ax 2D DWI		Ax 2D T2w	3D T1w Post[b]
Sequence	IR-GRE[d,e]	TSE[c]	EPI[f]		TSE[c]	IR-GRE[d,e]
Plane	Sagittal/Axial	Axial	Axial		Axial	Sagittal/Axial
Mode	3D	2D	2D		2D	3D
TR [ms]	2100[g]	>6000	>5000		>3500	2100[g]
TE [ms]	Min	100-140	Min		100-120	Min
TI [ms]	1100[h]	2200				1100[h]
Flip Angle	10°-15°	90°/≥160°	90°/180°		90°/≥160°	10°-15°
Frequency	≥172	≥256	128		≥256	≥172
Phase	≥172	≥256	128		≥256	≥172
NEX	≥1	≥1	≥1		≥1	≥1
FOV	256mm	240mm	240mm	**Contrast Injection** [a]	240mm	256mm
Slice Thickness	≤1.5mm	≤4mm	≤4mm		≤4mm	≤1.5mm
Gap/Spacing	0	0	0		0	0
Diffusion Options[i]			b = 0, 500, and 1000 s/mm^2 ≥3 directions			
Parallel Imaging	No	Up to 2x	Up to 2x		Up to 2x	No
Scan Time (Approx)	5-10 min	4-5 min	3-5 min		3-5 min	5-10 min

[a] 0.1 mmol/kg or up to 20cc (single, full dose) of MR contrast.

[b] Post-contrast 2D axial T1-weighted images should be collected with identical parameters to pre-contrast 2D axial T1-weighted images

[c] TSE = turbo spin echo (Siemens & Philips) is equivalent to FSE (fast spin echo; GE, Hitachi, Toshiba)

[d] IR-GRE = inversion-recovery gradient-recalled echo sequence is equivalent to MPRAGE = magnetization prepared rapid gradient-echo (Siemens & Hitachi) and the inversion recovery spoiled gradient-echo (IR-SPGR or Fast SPGR with inversion activated or BRAVO; GE), 3D turbo field echo (TFE; Philips), or 3D fast field echo (3D Fast FE; Toshiba).

[e] A 3D acquisition without inversion preparation will result in different contrast compared with MPRAGE or another IR-prepped 3D T1-weighted sequences and therefore should be avoided.

[f] In the event of significant patient motion, a radial acquisition scheme may be used (e.g. BLADE [Siemens], PROPELLER [GE], MultiVane [Philips], RADAR [Hitachi], or JET [Toshiba]); however, this acquisition scheme is can cause significant differences in ADC quantification and therefore should be used only if EPI is not an option.

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