Cerebral Tissue Contrast is Mostly Preserved in Low SAR Inversion Recovery MRI for Parkinson's Patients with Deep Brain Stimulators

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Purpose: Patients with Parkinson's Disease (PD) refractory to medical management may be treated with deep brain stimulation (DBS). Unfortunately, these implants carry severe restrictions on safe RF power.[1,2] While reports of sentinel events after MRI at higher RF power including serious brain injury or death are very few,[3] there are reports suggesting that MR performed at routine power levels may be responsible for neurologic deficits in some cases that previously had been attributed to surgery rather than imaging.[4] The average head SAR does not accurately reflect SAR near the electrode contacts in deep brain, which may be an order of magnitude higher. Strict MR conditional labeling[2] has limited the choice of MR parameters and hardware, yielding some margin of safety but also suboptimal image quality that is often unacceptable for planning of a second DBS in a patient who has just one, accurately assessing the location of electrodes in patients whose DBS treatments are sub-optimal, or even for routine diagnosis. To permit safe high quality MRI, we propose an ultra-low SAR sequence with utility for diagnosis as well as for surgery.

Methods: Using IRB approved guidelines, 13 patients with medically refractory Parkinson's disease (mean disease duration 11 years, age range: 55-78, 8 females) were imaged for 2-3 sessions (by high SAR for planning 1st DBS and low SAR for subsequent ones with refocusing pulse modifications, Table 1). Two neuro-radiologists and one neurosurgeon compared the high and low SAR images, the former for diagnostic quality and the latter for surgical planning. The brain regions assessed were: temporal lobe gray matter, caudate head, hippocampus, putamen, globus pallidus, thalamus, subthalamic nucleus and ventricular fluid. The subjective scores were divided into three categories: (I) low SAR images had higher tissue conspicuity than high SAR images (L > H); (II) low SAR images had lower conspicuity (L < H); and (III) tissue conspicuity was equal (L = H). Objective CNR for the tissues of interest (tissue 1) and adjacent white matter (tissue 2) were computed as: CNR = {SI(tissue 1)–SI(tissue 2)}/sd (air) , Figure 1. The mean CNR differences between the two methods were tested for significance by Wilcoxon's signed rank test.

Table 1. Sequence parameters for high and low SAR FSTIR and pulse modifications required to achieve low SAR at 1.5T GE Signa HDx using T/R head coil.

Pulse Sequence	TR/TE/TI/Matrix/Scan Time (min)	Slice Thickness/ FOV/Nex/Slices	Echo Train /BW (kHz)	Modified Refocusing Pulse Width (original widths)/Modified Flip Angles	Whole-Head SAR (W/kg)
High-SAR 2D Ax fSTIR (PD+T1w)	4s/12ms/140ms/ 256x192/5:30	3 mm/24 cm/2/30	8/±15.8	1.6 ms (1.6 ms)/180^0	1.5
Low-SAR 2D Ax fSTIR (PD+T1w)	10-13s/11-13ms/130ms 256 x192 /7:10-8:30	3 mm/24 cm/1/24 (Interleaved)	10/±15.8	2.6 ms(1.6)/first=110^0 second=100^0 rest of the refocusing angles= 100-110^0	≤ 0.1

Results: All 3 readers concluded that low and high SAR FSTIR images do not differ substantially in terms of visible SNR or tissue contrast and that low SAR image quality is adequate for diagnostic or surgical planning purposes. In several cases the low SAR images were deemed sharper than their high SAR counterparts (L>H entries, Table 2). However the mean CNR for the low SAR images was somewhat lower than the high SAR (20.0±8.7 vs 26.6±10.6, p≤ 0.05, excluding ventricular fluids, Fig 1). Low SAR images were useful for stereotactic planning in 9/13 patients; while for the rest the neurosurgeon had to resort to additional landmarks.

Table 2. Subjective scores indicating % PD patients with low SAR image quality higher (L>H), lower (L<H) or equal (L=H) to high SAR images.

Radiologists	STN and RN	Globus Pallidus	GM, CN and Putamen	Ventricular fluid/tissue margins
	L > H (27%); L < H (19%)	L > H (19%); L < H (8%)	L > H (27%); L < H (19%)	L > H (85%)
	L = H (54%)	L = H (73%)	L = H (54%)	L = H (15%)
Surgeon	STN/SN contrast for new DBS plan or localize prior DBS	Putamen/GP contrast for new DBS/localize old DBS	Temporal/parietal lobe image quality for assessing complications	Ventricles: size, shape, edge for planning DBS lead trajectories
	L = H (77%); L < H (23%)	L = H (69%); L < H (31%)	L = H (100%)	L = H (100%)

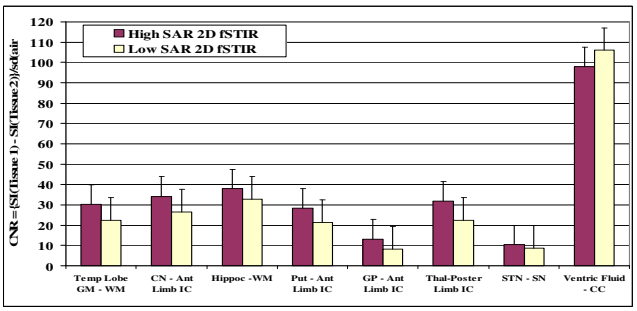

Fig 1. Mean tissue CNR from high and low SAR FSTIR images.

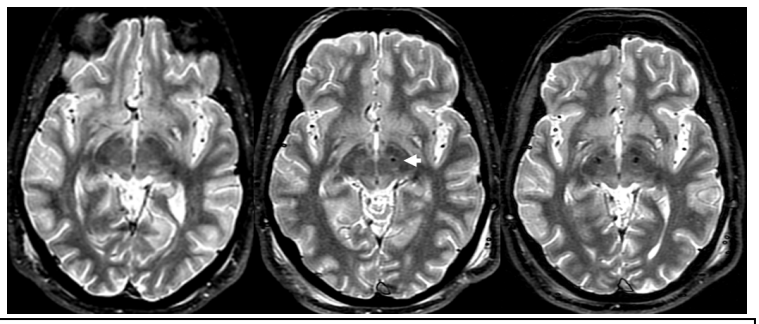

Fig 2. Typical FSTIR image. Left: pre-surgical at SAR=1.5 W/kg; Middle: planning for 2nd after 1st DBS, and Right: assessing surgical accuracy both at SAR=0.1 W/kg.

Conclusions: This work reports the development and clinical utility of a modified FSTIR sequence within strict hardware and SAR constraints in the presence of implanted DBS electrodes for medically refractory PD patients. Both the subjective and objective assessments indicate the tissue contrasts from the low and high SAR FSTIR methods are very similar and the majority of low SAR images are equally useful for radiologic diagnosis and stereotactic neurosurgical planning.

References: (1) Zrinzo L et al. Clinical Safety of Brain Magnetic Resonance Imaging with Implanted Deep Brain Stimulation Hardware: Large Case Series and Review of the Literature. World Neurosurg 2011:76:164. (2) Medtronic: MRI Guidelines for Medtronic Deep Brain Stimulation Systems 2007: Medtronic Inc. (3) Henderson JM et al. Permanent neurological deficit related to magnetic resonance imaging in a patient with implanted deep brain stimulation electrodes for Parkinson's disease: case report. Neurosurgery 2005:57:E1063, discussion E1063 (4) Zekaj E et al. Does magnetic resonance imaging induce tissue damage due to DBS lead heating? Acta Neurochir 2013:155:1677.