

### 3T MRI of patients with a vagus nerve stimulator: Initial experience under controlled conditions

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**Introduction:** 1.5T brain MRI of patients who have an implanted vagal nerve stimulator (VNS) is generally recognized as a safe procedure, provided that a transmit/receive (T/R) head coil is used and all of the recommended limits (in particular, SAR) are followed. For some applications, however, such as high-resolution brain imaging for pre-surgical planning in patients with epilepsy, the use of 3T can offer advantages over 1.5T [1]. Although safety of some implanted metallic devices such as VNS remains a concern for 3T MRI, many of the candidates referred to our practice with medically refractory epilepsy who would benefit from 3T MRI have an implanted VNS. The manufacturer advises caution when systems other than a 1.5T GE Healthcare MRI with a transmit/receive head coil are used, because adverse events may occur because of different magnetic field distributions. A recent publication [2], however, reported that the VNS device itself was not adversely affected by 3T scanning, and that its limited deflection in the 3T static magnetic field indicates that the magnetic force was less than the device's own weight. This implies that forces and torques on the VNS are not a serious concern at 3T. The gradient subsystem of the 3T MRI scanner is identical to that at 1.5T, suggesting that dB/dt is not a particular concern at 3T compared to 1.5T, either.

Reference 1 further reported that at 1.5T the in vitro heating measured with a T/R head coil in various configurations did not exceed 0.2° C with whole-body averaged SAR of 0.1 W/kg. (Because of the small portion of the body exposed to the RF field of the T/R head coil relative to the entire body weight, this power level typically corresponds to a much higher level of average head SAR, e.g., typically greater than 2 W/kg.) These results suggest that a 3T exam of a patient with an implanted VNS could be safe, provided that a T/R coil is used and SAR limits are followed. A letter to the Editor response [3], however, strongly cautions against extrapolation and generalization of the results of Ref. [2].

**Methods:** Phantom and volunteer tests verified that the spatial RF coverage of the 3T T/R head coil (Advanced Imaging Research Incorporated, Cleveland, OH, USA) did not exceed our standard GE 1.5T head coil, which has been extensively used to scan patients with implanted VNS, and is the same model studied in Ref [2].

Nine (9) communicative patients with an implanted VNS Therapy System (Cyberonics Inc., Houston, TX, USA) consisting of an implantable pulse generator (IPG) and VNS therapy lead underwent 3T MRI (GE Healthcare, Milwaukee WI, USA running 12.0 M4 software) with the T/R head coil. Average head SAR, as calculated and displayed by the scanner, was kept below 1.3 W/kg as monitored by an MRI physicist. The VNS was turned off prior to the exam, and the patients were instructed to use the squeeze-ball alarm at the onset of heating, discomfort, or any other unusual sensation. Patient well-being was monitored further by intercom communication between all imaging series.

The imaging protocol was modified so that no acquisition exceeded 1.3 W/kg average head SAR. This required that sagittal T1-FLAIR, coronal T2-FLAIR, and axial FSE series were divided into two or three acquisitions (each with a reduced number of slices) depending on patient weight and desired spatial coverage. Except for the T1-weighted volumetric acquisition (IR-SPGR or MP-RAGE), all images are acquired in 2D multi-slice mode. The multiple image acquisitions (e.g., the three parts of the T1-FLAIR) were retrospectively bound into a single series for presentation in PACS. The imaging protocol is briefly summarized in the table.

Series	1	2	3	4	5	6	7	8	9	10	11	12
	3-plane Localizer	Sag T1-FLAIR, part 1	Sag T1-FLAIR, part 2	Sag T1-FLAIR, part 3	Cor T1 (IR-SPGR /MPRAGE)	Cor T2 FLAIR part 1	Cor T2 FLAIR part 2	Cor T2 FLAIR part 3	Ax T2 FSE part 1	Ax T2 FSE part 2	Ax T2 FSE part 3	GRE T2*

**Results:** All 9 patient studies were completed without incident. No patient reported heating, discomfort, or any other unusual sensation. Representative image examples from series 5, 6-8, and 9-11 on a single patient are shown in the figure.

**Discussion and Conclusion:** The improved spatial resolution of the 3T exam compared to 1.5T is of value for the detection of subtle abnormalities and lesions. With the detection of a focal lesion, a patient can become a surgical candidate with the potential for great clinical benefit.

Our initial results show that under highly-controlled conditions, scanning of patients with an implanted VNS at 3T can be feasible. Because SAR approximately quadruples from 1.5 to 3.0T, three of the six imaging series were segmented into multiple scans. At this time, we only consider the use of 3T (versus the standard 1.5T) for VNS patients when there is a clear medical need, such as the pre-surgical planning for epilepsy. Extrapolation and generalization of these results to more general or less controlled imaging situations is highly discouraged [3].

**References:** 1. Briellmann RS, Pell GS, Wellard RM, Mitchell LA, Abbott DF, Jackson GD. MR imaging of epilepsy: state of the art at 1.5 T and potential of 3 T. *Epileptic Disord.* 2003; 5: 3-20. 2. Shellock FG, Begnaud J, Inman DM. Vagus nerve stimulation therapy system: In vitro evaluation of magnetic resonance imaging-related heating and function at 1.5 and 3 Tesla. *Neuromodulation* 2006; 9: 204–213. 3. Kainz W. Letter to the Editor response to Ref. 2. *Neuromodulation* 2007; 10 76-77.

