What is the SAR for Routine Clinical MRI Exams at 1.5T?

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INTRODUCTION: A principle safety consideration for all MRI exams is RF-induced heating of the patient and/or an implanted medical device. Each MRI sequence is monitored for RF energy deposition, which is regulated by the FDA using specific absorption rate (SAR, W/kg) limits[1]. Complementary measures such as B_1-RMS (μT) are also expected to be useful for defining implant safety guidelines, but the range of these measures for clinical exams is currently unreported. Understanding the time course of RF deposition during typical clinical exams may yield useful information for defining testing guidelines and device performance criteria for implanted devices. While testing at 4W/kg for 15-minutes[2] might be reasonable from a conservative MRI safety perspective we hypothesize that it is not typical of a clinical cardiac or neurological exam. Furthermore, evaluation of the duration of downtime between each sequence, which contributes to device cooling during routine clinical exams, is currently unreported, but necessary for simulating device heating during an exam. Our ***objective*** was to retrospectively characterize and evaluate scanner reported SAR, B_1-RMS and sequence timing for patients undergoing routine cardiovascular or neurological MRI exams in an outpatient imaging facility.

METHODS: Our retrospective IRB approved study acquired log-files with SAR information from a total of 123 cardiovascular and 96 neurological exams on a 1.5T scanner (Siemens Avanto) between November 2013 and April 2014. The log-file for each patient was parsed to extract: whole body and head SAR, B_1-RMS, and the start/end times of each sequence (seconds). Results are reported as a median with interquartile ranges (IQR).

RESULTS: Typical SAR histories are shown in Figure 1 for a cardiac and neurological exam. Figure 2 shows the B_1-RMS versus scanner reported SAR for cardiac and neurological exams. *Cardiac Exams* – The median whole body SAR for entire cardiac exams was 1.7 W/kg (IQR 0.5-3.2) and transiently exceeded 3.5 W/kg in 76% of patients and 3.8 W/kg in 23% of patients. The medium cumulative duration during which the whole body SAR was >3.5 W/kg for each patient was 5 minutes (IQR 3-9). The median sequence duration during a cardiac exam was 14 seconds (IQR 8-24) due to breath hold constraints. The median inter-sequence downtime was 31 seconds (IQR 21-49), largely due to the frequent pauses for breath hold recovery and scan planning. *Neurological Exams* –The median head SAR for neurological exams was 1.3 W/kg (IQR 0.6-2.3) and transiently reached 3.2 W/kg in 55% of patients. The median cumulative duration during which the head SAR was >2.0 W/kg for each patient was 10 minutes (IQR 6-12). The median sequence duration for a neurological exam was 157 seconds (IQR 103-230). The median inter-sequence downtime was 23 seconds (IQR 14-493). B1-RMS is quadratically related to SAR (Figure 2), but for a given B1-RMS there is a wide range of scanner reported SAR values.

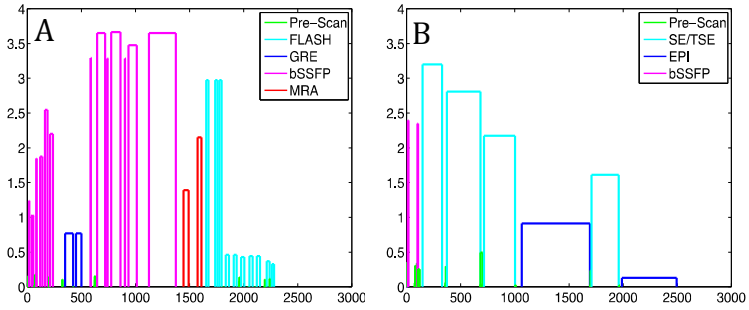

FIGURE 1. The SAR history for a routine cardiac (A) and neurological (B) exam is shown for representative patients. (FLASH-Fast Low Angle SHot, bSSFP-balanced steady-state free precession, MRA-Magnetic resonance angiography, and EPI-Echo Planar Imaging).

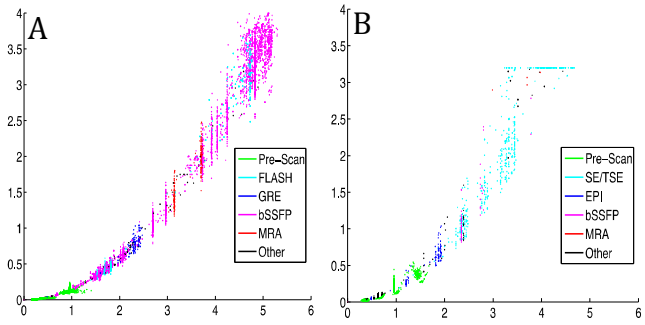

FIGURE 2. The B_1-RMS versus SAR is shown for all sequences performed on 96 cardiac patients (A) and 123 neurological patients (B); color-coded according to the type of sequence being run.

DISCUSSION: Our analysis of clinical cardiac exams shows that a majority of patients are exposed to a body SAR>3.5 W/kg, typically during bSSFP imaging, however, the cumulative duration at this SAR exposure remains relatively short at 3-9 minutes of a 51-minute exam. This data can be used in simulations to determine how realistic intervals of scanning and inter-sequence downtime during cardiac exams may affect device heating. Analysis of the clinical neurological exams shows that the majority of patients are exposed to the FDA limit for head SAR (3.2 W/kg), typically during turbo spin echo (TSE) imaging. These high SAR sequences run for approximately 6-12 minutes of a 32-minute exam. The comparison of B_1-RMS and SAR may be helpful to clinicians aiming to prospectively determine which diagnostic sequences can be acquired for a patient under MR-conditional SAR and B_1-RMS limits.

CONCLUSION: When considering how testing guidelines and performance criteria should be defined, our results provide substantial insight into the expected RF-exposure seen across a variety of routine clinical exams and can be used to simulate clinically relevant device heating.

REFERENCES: 1.http://www.fda.gov/cdrh/ode/guidance/793.html, 2. ASTM F2182 – 11a