Cardiac MRI Exams with Very Low SAR (0.1 W/kg) for Patients with Active Implantable Medical Devices

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Introduction

MRI-conditional active implantable medical devices (AIMDs), such as pacemakers or deep brain stimulators (DBS) are approved for MRI exams by the FDA, but include SAR limits as low as 0.1W/kg[1]. For typical cardiac MRI exams, however, the conventional limit is SAR≤2W/kg. Therefore, a modified MRI exam must be implemented to meet the device's MRI-conditional SAR limit.

The **objective** of this project was to use a specific workflow to modify a cardiac MRI protocol to achieve a target SAR≤0.1W/kg. The resulting images were then compared directly to those acquired with a conventional cardiac MRI protocol.

Theory

I. Specific Absorption Rate (SAR)

Scanner reported SAR is the amount of RF power deposited by the scanner and estimated to be absorbed by the body ([W/kg]). SAR is sequence and patient dependent, but it can be reduced by modifying certain sequence parameters (Figure 1).

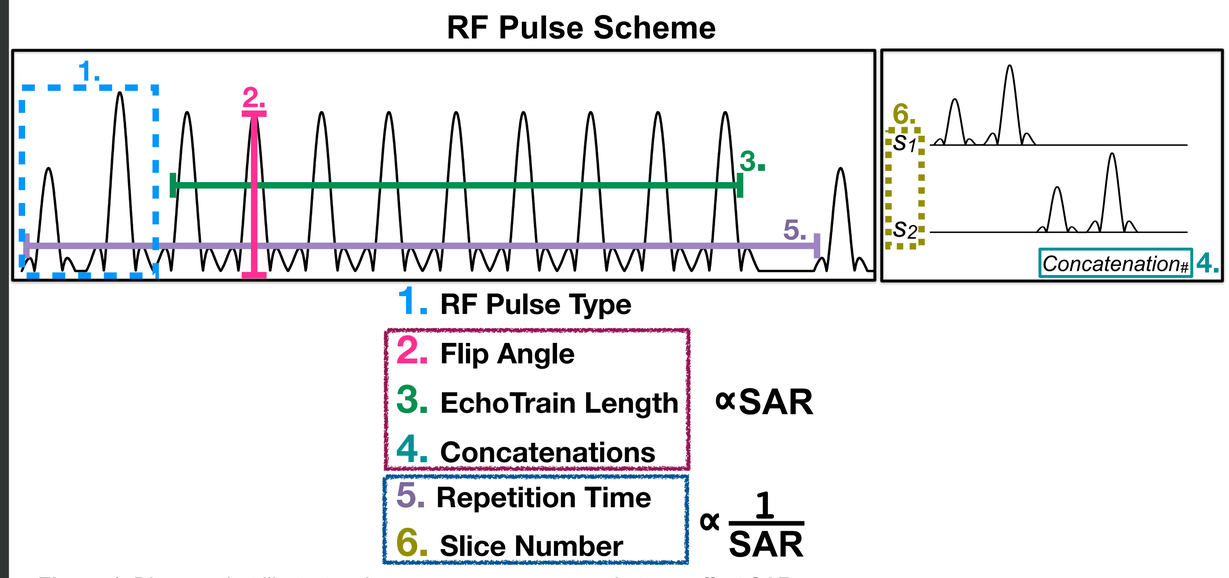

Figure 1. *Diagram that illustrates the sequence parameters that can affect SAR*

II. Workflow

Modifying sequence parameters without care can substantially compromise image quality. A workflow has been proposed to modify MRI protocols to meet a SAR target[2] (**Figure 2**).

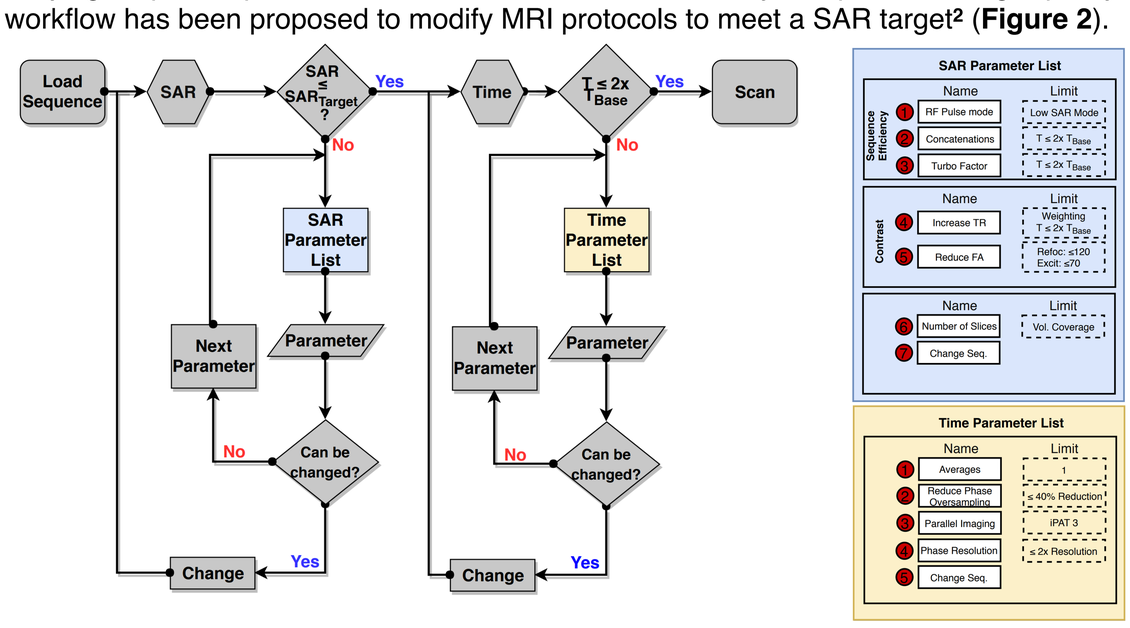

Figure 2. *Workflow used for reaching a SAR target while mitigating a negative effect on image quality. Sequence parameters are modified following a given order in an sequential manner.*

Methods

I. Protocol Modification

A standard cardiac MRI protocol, termed SAR_{ST}, was modified to achieve a SAR≤0.1W/kg, termed SAR_{LS}. The sequence parameters were modified using a systematic workflow (**Figure 2**). If SAR_{LS} could not be achieved while maintaining acceptable image quality, then the base sequence was changed from bSSFP to GRE (**Table 1**).

	Sequence Base			RF Pulse Mode			Repetition Time (ms)			Flip Angle (°)		
	Stan	*0.1*		*Stan*	*0.1*		*Stan*	*0.1*		*Stan*	*0.1*	
Localizers*	b-SSFP	b-SSFP	GRE	Normal	Low SAR	Low SAR	*309*	*928*	*628*	*60*	*30*	*15*
Anatomical	b-SSFP	GRE		Normal	Normal		681	1435		70	15	
Cine	b-SSFP	GRE		Normal	Normal		39	55		77		
Flow	GRE	GRE		Normal	Low SAR		41	42		30		
LGE*	b-SSFP	b-SSFP	GRE	Normal	Low SAR	Normal	700			65	45	15

Table 1. *Parameters modified for each sequence. * Refers to sequences which were able to be modified for reaching 0.1 W/kg for both bSSFP and GRE*

II. Image Acquisition

Cardiac MRI exams were performed at 1.5T (Avanto, Siemens) in healthy subjects under an IRB approved protocol (N=10, 7 females, 3 males, 81±45kg, 66±7bpm). The scanner reported SAR was recorded during each exam.

III. Quality Assessment

Likert Score – Images were scored by an expert radiologist on a 5-point Likert scale blinded to the imaging protocol. The scale accounted for both (i) clinical acceptability and (ii) image quality index. Scoring used: 1(extremely poor), 2(poor), 3(borderline good), 4(good) and 5(excellent).

SNR & CNR – Ten repeated image acquisitions were acquired in a T1/T2 phantom (Model130, QalibreMD) to calculate voxel-wise SNR maps. CNR analysis was performed by comparing a single slice with ROIs in regions where T1 values were similar to myocardium (950±23ms) and late enhanced scar (406±94ms)[3].

Results

Median whole body SAR values per sequence for both SAR_{ST} and SAR_{LS} are reported in **Figure 3**. SAR for SAR_{ST} was significant higher than SAR_{LS} (0.88±0.68 w/kg vs 0.05±0.03 W/kg, p-value<0.05).

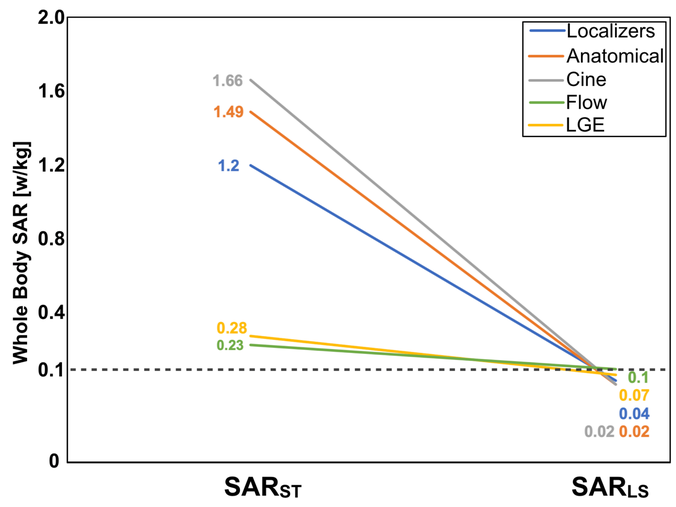

Figure 3. *Whole body scanner reported SAR for the five cardiac sequences. Dashed line indicates SAR limit of 0.1 W/kg.*

Image quality percentage count for both SAR_{ST} and SAR_{LS} is shown in **Figure 4**. Quality was higher, but not significantly for SAR_{ST} compared to SAR_{LS} (3.9±0.8 vs 3.1±0.7, p>0.05).

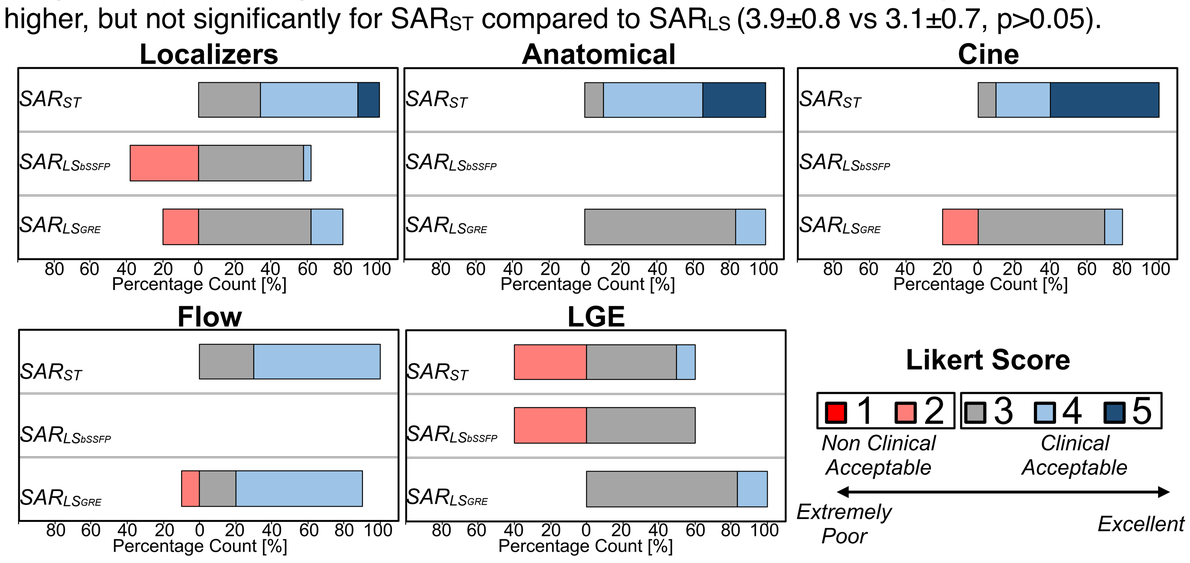

Figure 4. *Likert score count per volunteer for the five sequences*

Example images are shown in **Figure 5A**; SNR maps and CNR values are shown in **Figure 5B**. SNR values for the phantom region corresponding to myocardium was 53±59 for SAR_{ST} and 34±24 for SAR_{LS}. CNR values were maintained (SAR_{ST}:25±32, SAR_{LS}: 27±32, p>0.05).

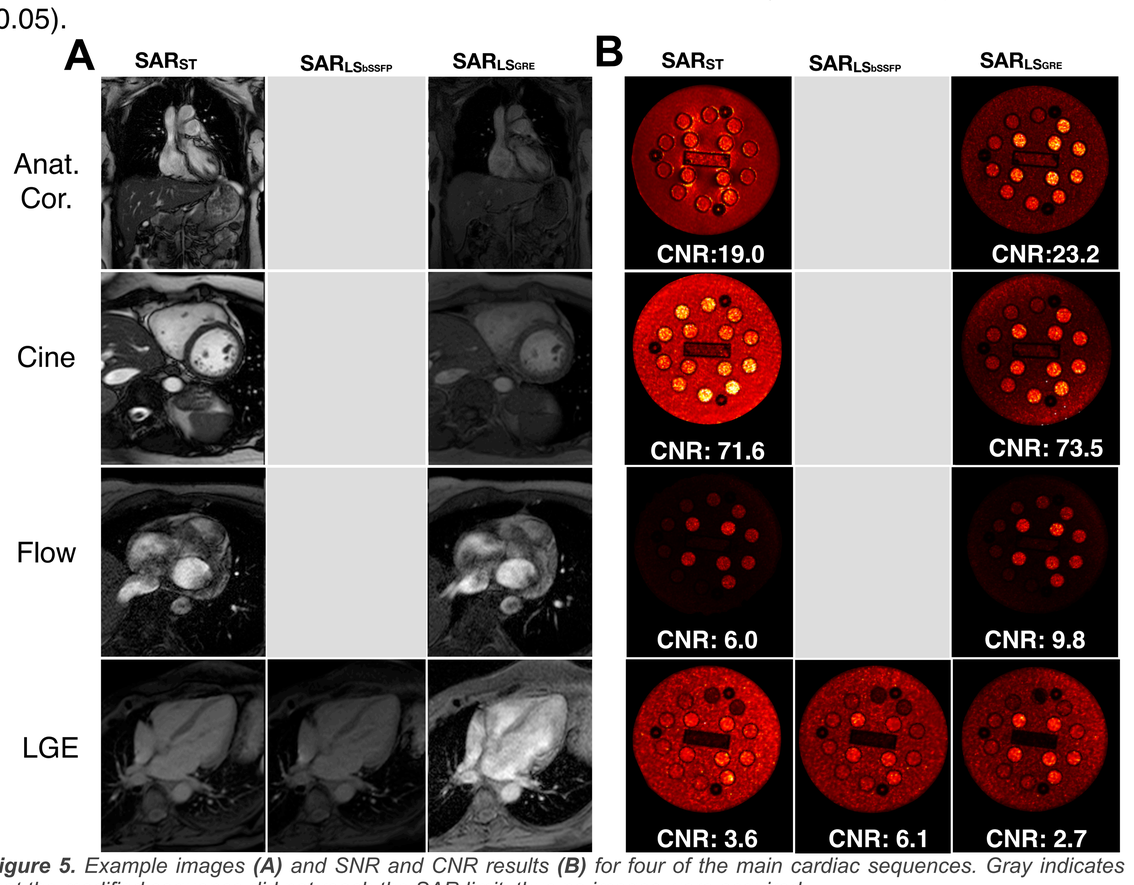

Figure 5. *Example images **(A)** and SNR and CNR results **(B)** for four of the main cardiac sequences. Gray indicates that the modified sequence did not reach the SAR limit, thus no images were acquired.*

Conclusions

This work provides feedback for both clinicians and device manufacturers on how to achieve a cardiac MRI protocol for patients with MRI-conditional AIMDs with low SAR labeling. A protocol with SAR≤0.1W/kg was achievable with limited impact on image quality, thus it can be used for clinical evaluation. Note, however, that the use of bSSFP sequences typically need to be replaced with GRE sequences.

References

1. Manker, SG et al, Neuromodulation, Elsevier 2018; 315-3337
2. Martinez, JA et al, ISMRM. 2018; 4078
3. Dabir, D et al, JCMR. 2014; 16(1):69

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