PRACTICAL APPROACHES TO ENSURE WE DO NOT EXCEED A NON-STANDARD SAR LEVEL

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Purpose. Specific absorption rate (SAR) values describe the amount of RF heating that an MRI sequence deposits in the person being scanned. Clinical MRI systems work to standard SAR levels (although these may vary slightly with geographic location, e.g. Europe versus North America). Many implantable devices are classified as "MR Conditional", with various conditions specified by device manufacturer that must be met prior to scanning anyone with these devices *in situ*. These conditions may include non-standard whole body and/or head SAR levels. On 1.5 T MRI systems from 3 major MRI vendors we investigated

1) how the different MRI systems appeared to predict the SAR value for a particular sequence and how this SAR value varied with patient weight.
2) how the various SAR levels were reported by the different MRI systems, both at the console to the MR operator and in the image DICOM header.
3) possibilities for creating a user-defined SAR-limit that would be enforced by the MRI scanner.

The aim of this abstract is to report these investigations and suggest possibilities for creating robust low SAR protocols, across the systems for imaging devices that require non-standard SAR limits.

Outline of Content.

How the different MRI systems appear to predict SAR

A spin echo sequence (TR=635, flip angle=90°, 26x5 mm slices) was implemented and acquired on all MRI systems over a range of phantom weights up to 87 kg, after which only the registered weight was increased. The predicted whole body SAR values show an unexpectedly large variation between the systems which is unlikely to be due to differences in each vendor's implementation of the spin echo sequence. System A and B appear to pre-calculate the predicted SAR leading to a value independent of phantom or patient loading. System C appears to determine predicted SAR based on measurements obtained during the sequence pre-pulse, hence it depends on transmit coil loading. For this reason a number of patient scans were investigated for system C for the same spin echo sequence (figure 1a). The predicted whole body SAR was found to be consistently lower than the equivalent phantom SAR. A similar comparison was made on system C for the predicted head SAR using the same patient data. This indicates that the patient predicted head SAR was consistently higher than the phantom predicted head SAR (figure 1b). Given this we suggest that phantom measurements alone cannot provide an accurate indication or even an upper limit to the SAR and a range of patients should be investigated for system C to determine the maximum potential SAR of a particular sequence. For vendors A and B however no such measurements are required since the scanner will always indicate the same SAR value for a particular patient weight (system A) or the same SAR value for all patient weights (system B).

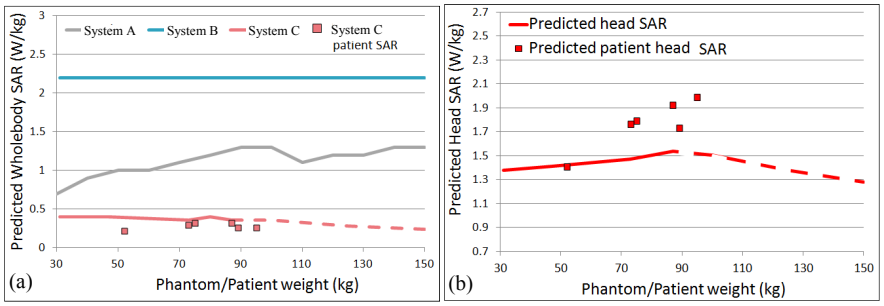

Figure 1: Predicted (a) wholebody and (b) head SAR for phantom and patients. Solid line: phantom weight = registered weight. Dashed line: phantom weight = 87kg

Table 1

		A	B	C
SAR displayed on console	whole body	✓	only for body coil transmit	✓
	head	T/R head coil only		✓
	whole body & head	T/R head coil only	X	✓
SAR recorded in DICOM header	whole body	Public DICOM SAR tag (0018,1316)		
	head	T/R head coil only, private DICOM tag	X	depends, private DICOM tag
	whole body & head	only for T/R head coil	X	depends

How the various SAR levels are reported on different MRI systems

Table 1 shows the observations for the MRI systems for SAR values displayed on the console and recorded in the DICOM header. The displayed SAR values for one system provided comprehensive information on the whole body, head and the two in combination, at the console. The other two systems only provided head SAR values at the console when using the transmit-receive head coil.

All MRI systems appeared to record the predicted whole body SAR level to the public DICOM tag for SAR in the image header. For two systems, additional information in private DICOM tags was available on the head SAR level, but in one case this was only provided if the transmit-receive head coil was used.

Can we specify a user-defined SAR-limit to be enforced by the MRI system?

With the scanners set to operate in standard clinical mode (no research key installed) none of the systems provided a facility to set user defined limits. However two of the MRI systems investigated allowed the user to implement non-standard SAR limits when in a research mode. The third system had no provision for any user-defined SAR levels. For system A, user defined limits were possible for wholebody SAR, head SAR and the two in combination. It should be noted however that in practice the user defined limits had to be manually chosen for each incidence of scanning. This potentially may mean that setting the user defined limits could be overlooked.

Table 2

		A	B	C
User-defined SAR levels?	whole body	with research access	with research access	X
	head	with research access	with research access T/R head coil only	X
	whole body & head	with research access	X	X

Summary

To our knowledge this is the first time comparisons of this type between MRI systems from different vendors have been investigated and reported, although previously SAR levels and resulting heating from the same sequence has been reported to vary significantly between different versions of MRI scanner from the same vendor [1]. The significant variation in the predicted SAR levels between vendors shown here is likely to be resulting in overly conservative SAR limits in some cases and inadvertently exceeding intended SAR limits in others. To resolve this, implant device manufacturers need to specify evidence-based SAR limits for all different MRI systems, which is clearly impractical, or either a harmonization of methods to predict SAR by the MRI vendors needs to be adopted. Alternatively a different measure of the RF magnetic field, such as the RMS value (B1,RMS) may be a more suitable measure for predicting the potential for RF-induced heating near an implant [2]. Finally, the ability to create a robust protocol for adhering to non standard head and whole body SAR limits is *very* limited, with some systems offering the ability to do this, but only when in research mode.

References.

[1] Baker *et al*. JMRI 24:1236–1242 (2006), [2] Baker *et al*. JMRI 20:315–320 (2004)