SAR and B_{1+}RMS

What is it?

MR sequences all use electromagnetic radiofrequency (RF) pulses. The safety of these pulses can be assessed by using either SAR or B_{1+}RMS:

- SAR stands for Specific Absorption Rate and describes the rate of energy deposition into tissue.
- B_{1+} is used to describe the amplitude of the RF magnetic field. B_{1+}RMS is the average effective magnetic field generated by a particular transmit coil for a particular sequence.

What are the Units:

SAR is generally reported in units of Watts (power) per kilogram (W/Kg). This refers to the *rate* of energy absorption per unit mass. B_{1+}RMS is reported in units of microtesla (μT)

Why is it important?

RF electromagnetic waves are used to generate signal in the patient. Unlike x-rays, for example, the RF used in MRI is not ionising. However, the RF used by MRI scanners causes some heating by depositing energy into the tissue. Note that this heating is both patient, scanner and sequence dependent.

MRI scanners **estimate** and restrict SAR according to the operating mode of the machine which is set to match limits specified by the International Electrotechnical Commission (IEC). There are different limits relating to different parts of the body, but the key limits often mentioned in guidance on implants are summarised in the table below. These limits practically implement more general safety guidance that restricts the allowed whole-body temperature rise to less than 1° C.

Operating Mode	Whole Body SAR limit (W/Kg)	Head SAR limit (W/Kg)
Normal	2	3.2
First-Level	4	3.2

Are there different limits for implants?

Implants can interact with the RF field of the scanner resulting in increased heating of the implant and surrounding tissues. Implants that are labelled as MR Conditional typically have a condition relating to SAR. If, for example, the SAR condition is for Whole Body SAR < 2 W/Kg, then this condition is easily met by restricting the machine to its Normal operating mode.

There are some implants that have MR Conditional SAR limits that are more restrictive. It may be necessary to use protocols that have lower SAR values and to actively monitor and record SAR during the scan to ensure that this condition is met.

Since SAR values can vary significantly between scanners and patients, implant manufacturers have started to quote the limit for B_{1+}RMS for a particular device. Since this value is patient independent it is a better limit to use. Recent scanner software versions allow a B_{1+}RMS limit to be entered. See the Faulkner reference for further information on how to find the $B1_{+}$RMS value on your scanner

Further Reading:

Allison J, Yanasak N. *What MRI Sequences Produce the Highest Specific Absorption Rate (SAR), and Is There Something We Should Be Doing to Reduce the SAR During Standard Examinations?*
AJR Am J Roentgenol. 2015 Aug;205(2):W140.

MHRA 2016: Safety Guidelines for Magnetic Resonance Equipment in Clinical Use, https://www.gov.uk/government/publications/safety-guidelines-for-magnetic-resonance-imaging-equipment-in-clinical-use

Faulkner W. New MRI Safety Labels & Devices. https://www.ismrm.org/smrt/E-Signals/2016FEBRUARY/eSig_5_1_hot_2.htm
https://www.sor.org/learning/document-library/safety-magnetic-resonance-imaging/7-radio-frequency-radiation-b1

The British Institute of Radiology
48-50 St John Street
London
EC1M 4DG

T : +44(0)20 3668 2220
E : admin@bir.org.uk