Low SAR – Why, when and how

MRI depends fundamentally on radio frequency (RF) electromagnetic fields. The RF magnetic field (termed B_1^+) performs the flipping of the net magnetisation. Eddy currents induced by the alternating magnetic field in electrically conductive materials, such as body tissue, results in heating. The power deposition per unit mass is termed specific absorption rate (SAR) and is measured in W/kg. SAR is influenced by patient demographics, including height and weight.

The international standard IEC 60601-2-33 defines limits for SAR, to prevent excessive rise in body temperature. Two distinct modes are defined – normal operating mode, which is not expected to cause physiological stress, and first level controlled operating mode where there is a risk of physiological stress. There are uncertainties related to the effect of heat loads on infants and in pregnancy, and patients with impaired physiological control mechanisms due effects of age, disease (e.g. fever, cardiac decompensation) or treatment (e.g. chemo/radiotherapy). In modern practice, the SAR limits above may not be sufficient to cover all clinical scenarios. Implanted devices, particularly those containing electrically conductive materials can cause concentration of the electric fields, resulting in regions of intense heating; this is not something which the normal and first level controlled operating mode limits are intended to protect against.

Manufacturers of medical devices which may be exposed to MRI are expected to determine device specific limits for heating and state these in the device instructions for use. Some implants may require the use of a SAR limit lower than normal operating mode (e.g. some orthopaedic implants or vascular stents). Some implant manufacturers may specify their limits directly as B_1^+rms, particularly in the case of active implants. B_1^+rms is subject to fewer uncertainties than SAR. Additionally, B_1^+rms is computed with a shorter averaging time (10 s) than SAR (6 min) which may be better suited for modelling intense heating around small conductive parts.

Reducing SAR requires reducing the rate of delivery of RF energy. This often requires increasing the scan duration, reducing SNR, resolution, contrast, anatomical coverage or a combination. MRI manufacturers may have software which can assist with parameter changes, or pre-defined libraries.

Parameter	Disadvantages
Increase TR	Increase in scan duration Degrades T1 contrast
Reduce flip angle	Will change SNR Will change contrast
Use low SAR RF pulses	Reduced maximum echo train length (ETL) and hence increased scan duration
Reduce number of slices	Reduced anatomical coverage (may require multiple sequences to complete examination)
Reduce number of averages	Reduced SNR

Where particularly demanding and major changes to parameters are required, it is advisable to check diagnostic quality for various clinical scenarios (e.g. review of volunteer images by a radiologist or reporting radiographer). Where frequent use of low SAR sequences is expected, the development of a low SAR standard protocol library can save time.

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