



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?

The radiofrequency power delivered to tissue during an MRI examination is referred to as the SAR, expressed as watts per kg (W/kg). Radiofrequency power deposition results in heating of patient tissues. MRI scanners have radiofrequency power limits that keep the radiofrequency power deposition to levels that are safe for most patients. The lowest level is referred to as “normal.” A higher level, referred to as “first-level controlled,” requires medical supervision of the patient before scanning can proceed.

The concern for a rise in tissue temperature is greater in certain patients:

- Patients with reduced thermoregulatory capacity
 - Cardiac impairment
 - Hypertension
 - Diabetes
 - Old age
 - Obesity
 - Fever
 - Impaired ability to perspire
 - Pregnancy (risk for fetal heating)
 - Drug regimes that may affect thermoregulatory capabilities (diuretics, tranquilizers, vasodilators)
- Patients in a cast (risk of thermal insulation)
- Patients who are unable to sense or communicate heat sensations (risk is no self-report of comfort during scanning due to patient being unconscious, sedated, locally anesthetized, or confused)
- Patients with extensive tattoos (risk is potential for radiofrequency burns)
- Patients with implanted organs or devices may have much higher risk from exposure to MRI radiofrequency pulses and must be evaluated individually.

Some patient monitoring techniques (ECG, pulse oximetry) may cause increased risk to

the patient if not removed and must be carefully evaluated. A helpful list is presented on the mrisafety.com website [1].

In MRI, pulses of radiofrequency energy are used to generate signals used in image formation. The radiofrequency pulses consist of oscillating electromagnetic fields. Because patient tissues can conduct electrical current, exposure of tissue to radiofrequency pulses results in electrical currents that produce heating. The amount of tissue heating depends on the magnitude of the radiofrequency pulses and how frequently the radiofrequency pulses are applied. Spin-echo MRI techniques use large radiofrequency pulses for the 90° and 180° manipulation of tissue magnetization. Fast spin-echo (FSE) techniques apply large radiofrequency pulses very rapidly. As a result, spin-echo techniques, particularly FSE, deliver more radiofrequency power, resulting in higher SAR and relatively more tissue heating. Gradient-echo techniques use much smaller radiofrequency pulses. Even though gradient-echo techniques apply radiofrequency pulses very rapidly, the net deposition of power is lower, resulting in lower SAR and less tissue heating. However, certain gradient-echo sequences, e.g., time-of-flight MR angiography, apply radiofrequency pulses at such a high speed that they also result in high SAR. To help monitor heating of patient tissue, the MRI scanner estimates the SAR of each acquisition on the basis of the technical details of the scanning acquisition and patient weight. The SAR estimate is displayed on the scanner console before scanning is initiated.

The International Electrotechnical Commission sets standards for MRI [2] (Table 1). Even though these regulatory limits exist, it is important to note each vendor differs as to how to estimate SAR. Therefore, the number reported by the scanner should not be taken as

a solid “limit” on safety. The SAR reported by the scanner should be taken as a quantitative estimate with some degree of inaccuracy.

There are several approaches for managing SAR. Most SAR reduction approaches have associated imaging consequences. These approaches are as follows:

- Increase the TR, which can lead to longer scanning times.
- Reduce flip angles (for FSE sequences, use 60–130° refocusing pulses rather than 180° refocusing pulses), which can alter image contrast-to-noise ratio or signal-to-noise ratio.
- Reduce the number of slices in an acquisition, which can lead to longer scanning times.
- Reduce the number of echoes in multiecho sequences, which can lead to longer scanning times.
- Control the scanning room temperature and humidity (follow manufacturer specifications), which may affect comfort for lightweight patients.
- Dress the patient in light clothing, which may affect patient modesty.
- Take breaks between high SAR acquisitions or interleave high SAR and low SAR acquisitions to allow patient cooling, which can lead to longer scanning times.
- Be sure the patient ventilation system in the scanner is turned on.

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References

1. THE LIST, MRIsafety.com website. www.mrisafety.com/TheList_search.asp. Accessed April 16, 2015
2. International Electrotechnical Commission (IEC) website. IEC 60601-2-33 (ed. 3.1) sets standards for MR, medical electrical equipment. Part 2-33. Particular requirements for the basic safety and essential performance of magnetic resonance equipment for medical diagnosis. www.document-center.com/standards/show/IEC-60601-2-23. Published February 11, 2011. Accessed April 16, 2015

TABLE 1: International Electrotechnical Commission Standards for MRI [2]

Operating Mode	Whole-Body SAR (W/kg)	Head SAR (W/kg)	Maximum Rise of Core Temperature (°C)
Normal	2	3.2	0.5
First-level controlled (medical supervision)	4	3.2	1

Note—SAR = specific absorption rate.