MRI Safety
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3 Powerful Magnetic Fields
- Static
- RF
- Gradient

Magnetize the Tissues

Excite the Protons / Detect Signals

Localize the Signals

Static Magnetic Field
- Vertical Field
- Horizontal Field
Superconductivity

The electrical resistivity of a metallic conductor decreases gradually as temperature is lowered. In ordinary conductors, such as copper or silver, this decrease is limited by impurities and other defects. Even near absolute zero, a real sample of a normal conductor shows some resistance. In a superconductor, the resistance drops abruptly to zero when the material is cooled below its critical temperature. An electric current flowing through a loop of superconducting wire can persist indefinitely with no power source.

Field Strength

1 Tesla = 10,000 Gauss

The earth’s magnetic field is approximately 0.5 Gauss

Small bar magnet is approximately 100 Gauss

1.5 Tesla MRI system is 15,000 Gauss, 30,000 x the earth’s magnetic field

The magnet is always on
Powerful **Persistent** Magnetic Field

3.0 Tesla MRI system is
30,000 Gauss
60,000 x the earth’s magnetic field

The magnet is 
always on

July 2001
Radio Frequency

RF Burns

3rd Degree from Pulse Ox

www.simplyphysics.com

Initial Injury

Few days later

Always use proper insulating pads
Skin-to-Skin Contact

Street Clothes Can Be Dangerous

Blouse catches fire during 1st sequence of a shoulder exam. 3rd degree burns to forearm.

-FDA MAUDE database

Radio Frequency B₁

Heating

Tissue

Device

Radio Frequency B₁

Heating

Tissue

Device
Specific Absorption Rate

If input is greater than output, heating occurs

\[ \text{Power In} - \text{Power Out} = \text{SAR} \]

Currently clinical systems cannot exceed 4 W/kg whole body

Normal Mode: No physiologic stress is expected
1st Level Mode: Physiologic stress can occur

From a GE system
Various underlying health conditions may affect an individual’s ability to tolerate a thermal challenge including cardiovascular disease, hypertension, diabetes, fever, old age, and obesity. In addition, medications including diuretics, beta-blockers, calcium blockers, amphetamines, and sedatives can alter thermoregulatory responses to a heat load. Importantly, certain medications have a synergistic effect with RF radiation with respect to tissue heating. The environmental conditions (i.e., ambient temperature, relative humidity, and airflow) that exist in the MR system will also affect tissue temperature changes associated with RF energy-induced heating.”
Field Strength, Frequency, Wavelength

wavelength @ 3 T is approx 2.4 meters
20 - 25 cm “worse case”

Cervical Fixation Device at 3.0 T

For elongated or closed loop implant or device implant, heating can differ significantly at different field strengths.

MRI-Related Lead Heating: Pacing Lead, No IPG

1.5 (1.4-W/kg) vs. 3-T (3-W/kg)

For certain lead lengths, less heating at 3-T/128MHz vs. 1.5-T/64MHz due to differences in resonant wavelength.

T/R Head Coil vs. Transmit Body/Receive-only Head Coil

T/R

For configuration, Philips vs. GE:

Philips: Receive-only
GE: Transmit/Receive

Two Serious Injuries @ 1.0 T

Guidelines not followed

1.5 T ONLY
T/R Head coil ONLY
Head SAR 0.1 W/kg
Time-Varying Magnetic Fields

Gradient fields used for imaging

Used for spatial encoding

Strong magnetic fields that switch rapidly during imaging

Current induction in conductive loops

Size and shape

Conductive properties

Position / Location

Gradient slew rate

Peripheral Nerve Stimulation

Current induction in conductive loops

Faraday’s Law of Induction

Changing field

\[ \mathcal{E} = \frac{dB}{dt} \text{ time} \]

Eddy Current Induction

Vibration

Device / component damage

“Decisions based on published MR safety and compatibility claims should recognize that all such claims apply only to specifically tested conditions, such as static magnetic field strengths, static gradient magnetic field strengths and spatial distributions, and the strengths and rates of change of gradient and radiofrequency (RF) magnetic fields.”

ASTM Standard F2503 Defines Three Terms:

- **MR Safe**
- **MR Unsafe**
- **MR Conditional**
**MR Safe**

An item that poses no known hazards in all MR environments

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**MR Unsafe**

An item that is known to pose hazards in all MR environments

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**MR Conditional**

An item that has been demonstrated to pose no known hazards in a specified MR environment with specified conditions of use

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**Gadolinium**

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**chelate**, any of a class of coordination or complex compounds consisting of a central metal atom attached to a large molecule, called a ligand

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"...recently emerged among patients with renal disease"

"...recent emergence of this condition"

"...suggested a possible infectious and/or toxic agent"

Published data: frequency of NSF not equal among all agents

(Radiology 2008, 10.1148/radiol.2483072093)
ACR Grouping

Stability

No Unconfounded Cases of NSF
- ProHance
- Dotarem
- MultiHance

Contraindicated with eGFR < 30
- Magnevist
- Omniscan
- OptiMARK

Understand the risks

Provide the best outcome while minimizing risks