MR Safety Officer Fact Sheet

Definitions

Static Magnetic Field

Term	Definition
Active Shielding	To diminish the fringe field, a wire coil with an electrical current running through it is used to generate an electromagnetic field opposing the static magnetic field.
Bsub0	The unit of measurement for the static magnetic field.
Deflection	The degree to which an item is attracted to a static magnetic field.
Diamagnetism	When put in a high static magnetic field, it has a mildly repelling force.
Faradays Law of Induction	This covers the generation of electrical currents in the presence of alternating magnetic fields.
Ferromagnetism	In a strong static magnetic field, an item with a strong attractive force that keeps a magnetic field even after leaving the strong static magnetic field.
Flux Lines	The gradient in magnetic densities that moves from the north pole to the south pole of a static magnetic field.
Fringe Field	The magnetic field that goes beyond the confines of the MR unit.
Gauss	A magnetic field measuring instrument.
Horizontal Static Magnetic Field	A horizontal magnetic field vector.
Lenz's Force	When nonferrous items are transported through a strong static magnetic field, they produce a magnetic field.

Magnetic Field Strength	The magnetic field strength of the MR device as a whole.
Magnetic Moment	Each hydrogen proton generates its own magnetic field.
Magnetohydrodynamic Effect	A patient's blood becomes magnetized when exposed to a high static magnetic field. This results in an increased T wave during their cardiac cycle.
Paramagnetic	When put in a static magnetic field, a weakly attracting force.
Passive Shielding	Magnetically conductive materials are used in an MR unit to minimize the fringe field.
Pauli Exclusion Principle	The concept that defines atom structure and magnetism kinds (ferromagnetism, paramagnetism, diamagnetism...).
Rotational Force	A force that directs the flux lines of things is influenced by the static magnetic field.
Spatial Gradient Magnetic	The shifting magnetic field intensity is seen at various distances from the MR device.
Static Magnetic Field	The magnetic field that aligns parallel or anti-parallel hydrogen nuclei.
Superparamagnetic	When put in a high static magnetic field, it has a larger attractive force than superparamagnetic but not as strong as ferromagnetism.
Teratogenic	The effects of a static magnetic field on the children of those who have been exposed to it.
Tesla	The measuring unit is used to characterize the static magnetic field.
Translation Force	An object's attractiveness as it moves through a static gradient magnetic field.
Vector	The static magnetic field's direction.
Vertical Static Magnetic Field	A vertical magnetic field vector.

Time-varying Gradient Magnetic Fields

Term	Definition
Axial Imaging	This is a collection of images generated when the Z gradient is engaged.
Coronal Imaging	This is a collection of images generated when the Y gradient is active.
Duty Cycle	The duration during which the gradient coils can remain active.
Golay Coil	A pair of saddle electromagnetic coils is situated on the patient's right and left sides, as well as anterior and posterioat create strong magnetic fields from left to right and anterior to posterior.
Gradient Steepness	The gradient's slope or amplitude when enabled.
Logical Gradient	Gradient activation is a term used to describe data collection gradient activation. This is the slice selection gradient, the phase encoding gradient, and the frequency encoding gradient.
Lorenz Force	The torque experienced by the MR gantry when the gradient coils are triggered. This causes the sounds heard in an MRI.
Magnetophosphenes	When exposed to a fluctuating magnetic field, you may see flashing lights. This is due to nerve activation, which is explained by Faraday's law of induction.
Maximum Gradient Field	The greatest amplitude ever seen.

Maxwell Coil	A ring of electromagnetic coils situated at the patient's foot and head that created a high gradient magnetic field from head to foot.
Noise Reduction Rating	This is a method of calculating the amount of noise lowered by earplugs or headsets.
Nystagmus	When exposed to a fluctuating magnetic field, the eyeballs move uncontrollably. Faraday's law of induction describes how nerve stimulation causes this.
Peripheral Nerve Stimulation	When exposed to a changing magnetic field, nerves are activated. This is due to nerve activation, which is explained by Faraday's law of induction.
Physical Gradient	The phrase used to describe the gradient coils' spatial encoding. The X gradient generates sagittal pictures, the Y gradient generates coronal images, and the Z gradient generates axial images.
Precession	The wobbly motion that hydrogen nuclei exhibit.
Rise Time	The time it takes for the gradients to reach the maximum amplitude of the series.
Sagittal Imaging	This is a collection of images generated when the X gradient is engaged.
Slew Rate	The rate at which gradient coils may alter gradient magnetic fields.

Time-varying RF Fields

Terms	Definition
90 Degree RF	The amount of energy required to shift hydrogen from longitudinal magnetism to transverse magnetism.
180 Degree RF	The amount of energy required to rotate a hydrogen atom is 180 degrees. This is used to reestablish phase coherency in a spin echo sequence.
Body Habitus	Classification of body kinds based on shape and size.
Bsub1	The unit of measurement for the time-varying RF magnetic field.
E-Fields	When a conductive substance is subjected to a changing magnetic field, it produces an electrical field.
Electromagnetic Spectrum	The frequency spectrum identifies the amount and shape of energy found at certain frequencies.
Faraday's Law of Induction	This describes the generation of electrical currents in the presence of alternating magnetic fields.
Far Field	The section of our gantry is farthest away from the RF transmitter.
First Controlled Mode	This is a mode in which the maximum regulated SAR limit is permitted during acquisition. This is restricted to 4W/kg for the entire body.
Flip Angle	A variable RF pulse tilts hydrogen away from the longitudinal axis by less than 90 degrees.
Frequency	The frequency with which something is repeated throughout time.

Hertz	The number of waveforms in one second.
Larmor Equation	The equation for determining the center frequency for a given static magnetic field intensity. Processional frequency=gyromagnetic ratio * B0
Longitudinal Recovery	The time following an excitation pulse when magnetism returns to equilibrium magnetism.
Loop Burns	A form of burn in which an electrical current is produced in a patient and driven via a limited contact region, resulting in a burn.
Near Field	The section of our gantry nearest to the RF transmitter.
Non-ionization	A kind of energy that does not harm biological tissues.
Normal Mode	This is a normal mode of operation in which the SAR for the entire body is limited to 2 W/kg.
Parallel Imaging	This is a method in which two or more coils work together to gather numerous lines of K space at the same time.
Radio waves	The frequency range that is employed in MRI to induce resonance.
Receive Only Coil	A receiver coil that solely detects patient-emitted signals.
Reflective Burns	This is a burning condition in which RF is reflected back to the patient, causing burning.
Resonance	The transfer of energy from one object to another by two or more objects pulsating at the same frequency.

Resonant Burns	This is a form of burn in which resonance is created in an implant or equipment on a patient, resulting in induction. The e fields generated will create fires.
Proximity Burns	This is a sort of burning in which tissues in the immediate vicinity are burnt.
Second Controlled Mode	This is a research or testing mode in which the SAR can operate over the maximum regulated limit.
Specific Absorption Rate	This is used to calculate the amount of patient heating produced during acquisition. It is measured in watts per kilogram.
Thermoregulatory Mechanisms: Evaporation	Sweat is released by the body through pores, allowing for evaporation. This evaporative cooling can aid in the reduction of body temperature.
Thermoregulatory Mechanisms: Conduction	It is possible to transfer energy from one source to another. Flowing blood may be chilled by placing a cold source on our patient, reducing the patient's body temperature.
Thermoregulatory Mechanisms: Convection	Heat radiates from a hot spot to a colder location. Heat may be moved away from a patient by blowing cool air over them, reducing their body temperature.
Thermoregulatory Mechanisms: Radiation	Heat will escape from a patient's body.
Transmit-Receive Coil	A receiver coil that generates RF energy and detects patient signals.
Transverse Decay	The time following an excitation pulse when magnetism in the transverse axis is lost.
Wavelength	The distance between two amplitudes in a frequency.

Cryogen

Terms	Definition
Asphyxiation	A situation in which the body's oxygen levels are exceedingly low.
Cryogen	A very cold material.
Duel Cryogen System	Nitrogen is used in this method to keep helium cool.
Frostbite	Skin conditions induced by freezing.
Helium	This is utilized to keep a superconducting magnetic resonance imaging (MRI) unit producing high field strengths.
Hypothermia	Having a dangerously low body temperature.
Kelvin	This is a unit of measurement for measuring extremely cold things.
Ohm’s Law	In an electrical circuit, this explains the relationship between resistance, voltage, and current. R=V/I
Quench	This is the procedure of removing cryogen from a superconducting MR device to allow the static magnetic field to diminish.
Quench Vent	This is the route through which helium can be released from the MR unit.

Gadolinium Contrast Media

Terms	Definition
Allergic Reaction	A response to a contrast medium that causes the body to manufacture histamines can have catastrophic consequences for the patient.
Anaphylactic Reaction	A severe response to contrast media.
Anthropogenic	Gadolinium contrast is introduced into the drinking water system from patients who have received gadolinium contrast.
BBB	The capillary barrier in the brain stops undesired chemicals from passing through.
Blood-Pool Contrast	A form of contrast media that attaches to proteins (albumin) in the blood, allowing it to remain intravascular for a longer period of time. This is used to create a picture of the vascular system.
Chelate	A method of attaching a metal ion (gadolinium ion) to a molecule such that it may be readily removed from the body.
Extracellular Contrast	Extracellular contrast media is a form of contrast media. The CNS is imaged using this technique.
Gadolinium Associated Plaque	Gadolinium-containing plaques develop on the patient's skin.
Gadolinium Retention	Gadolinium deposits in the body of people with normal renal function.
Glomerular Filtration Rate	A number that indicates the stage of renal failure in which a patient is.

Hepatobiliary Contrast	A form of contrast material secreted largely by the liver and utilized in hepatic imaging.
Ionic Contrast	When dissolved in a solution (blood), a charge is formed between the gadolinium ion and the ligand, resulting in a stronger bond.
Ligand	A molecule that forms a coordination complex by binding a metal (gadolinium ion).
Linear	A ligand has a linear design structure that binds a gadolinium ion to it.
Long-term Adverse Effects	An unfavorable reaction to a contrast medium that develops days, months, or years after the contrast was given.
Macrocyclic	A ligand structure that "cages" the gadolinium ion.
Nephrogenic System Fibrosis	When individuals with impaired renal function are exposed to the gadolinium contrast, fibrosis occurs on the skin and internal organs.
Non-Allergic Reaction	A reaction to a contrast medium that does not entail the release of histamines in the body. Instead, it is a response to the agent's action injection.
Non-ionic Contrast	A contrast in which there is no charge between the gadolinium ion and the ligand.
Relaxivity	The quantity of T1 shortening generated by a contrast agent.
Viscosity	A contrast agent's thickness.
Short-Term Adverse Effects	An unfavorable reaction to a contrast agent that happens minutes, hours, or days after administration.

Transmetallation	The process through which a ligand loses a gadolinium ion and gains another metal ion (zinc).

Guidelines

Terms	Definition
5 gauss Line	A distance from the MR unit where the magnetism ogaussesauss is shown. This is the region where electrical equipment problems can occur.
ACR Guidance Policy 2013	A publication that describes the safest MR protocols for clinical usage.
American College of Radiology	An organization that specifies radiology's safety procedures and excellence.
American Society for Testing and Materials	An international standard that specifies technical specifications for a wide range of products and equipment.
ASTM F2503	Implant and object standards in the MR environment.
Captain of the Ship Doctrine	A law that makes one person responsible for activities taken during an MR procedure.
Criminal Case	A case involving a violation of the law that can result in a fine or jail time.
Defendant	An individual suspected of committing a crime.
Deposition	Sworn testimony of the facts from the perspective of a specific individual participating in a court hearing.

Discovery	A procedure for gathering information about people named in a case.
Emergent Patient	A patient who requires urgent scanning. A STAT is one such example.
Felony	A serious infraction that can result in a fine or jail time.
Ferro detector	A gadget capable of detecting ferrous materials.
Food and Drug Administration (FDA)	A regulatory organization in the United States that oversees public safety.
IEC 60601-2-33	A rule that specifies the criteria for normal mode, first controlled mode, second controlled mode, and additional modes.
Infraction	A small infraction that usually results in a fee.
International Electrotechnical Commission	A non-profit organization that develops standards for electro-technology devices.
MedWatch Program	An FDA-regulated program that keeps track of any events or near misses affecting the MR environment.
Malpractice	An act that entails failing to satisfy a standard of care and causing injury to a patient as a result.
Metal Detector	A gadget capable of detecting metal.
Misdemeanor	A more serious crime than an infraction that can result in a fine or prison time.

MR Conditional	An ASTM marking that states that an object is safe to enter the MR environment if certain standards are followed.
MR Medical Director	An MR employee level 2 with a strong awareness of MR safety who can make the ultimate decision in a problematic safety issue and participate in regulations that control the safety of an MR environment.
MR Personnel Level 1	A person who has received MR safety training during the last 12 months.
MR Personnel Level 2	An individual who has just earned considerable MR safety instruction and expertise.
MR Safe	An ASTM-defined label indicating that an object is safe to enter the MR environment.
MR Safety Officer	A level 2 MR worker who understands MR safety and is responsible for recognizing possible MR dangers as well as knowing safer ways to scan them.
MR Screening Sheets	A form that a patient must fill out or have orally taught to them by a level 2 MR personnel in order to identify any possible MR dangers.
MR Unsafe	An ASTM label that warns that an item in the MR environment may constitute a hazard to a patient.
National Electrical Equipment Manufactures Associations	A group that creates technological standards.
Neglect	An act that entails failing to satisfy a patient's standard of care.
NEMA MS1-9	Defines operational guidelines in an MR context.

Non-Emergent Patient	A patient who has a regular exam conducted during department hours.
Non-MR Personnel	A person (patient's family member, fireman, etc.) who has not undergone MR safety training in the recent 12 months and requires supervision in the MR environment.
Patient	A person who is having an MR test.
Plaintiff	In a court of law, a victim.
Tester Magnetic	A stronger magnet than 1000 gauss that may be used to determine how ferrous a possible MR hazard is.
Tort Case	A case involving injury to a person or property that usually entails the payment of monetary compensation.
Zone I	A case involving injury to a person or property that usually entails the payment of monetary compensation.
Zone II	This is an area open to the general public with the supervision of an MR employee level 1 or 2.
Zone III	This is a zone IV-accessible region that requires just MR-screened patients and MR employees.
Zone IV	The MR unit is located in a highly controlled region. In this location, no ferrous items or unscreened patients are permitted. In addition, no patients or non-MR workers are permitted in this area unless supervised by MR personnel level 2.

Zoning

<u>Zone I</u> **<u>Public Zone</u>** *· Open to the general public* *· Contains no risk to the general public* *· Unrestricted*		**<u>Zone II</u>** **<u>Patient Preparation Zone</u>** *· Waiting room, Changing room* *· Get a history from the patient* *· Unscreened patients can be present (patients screened for MRI) · Area unable for patients to move around freely*	
			<u>Zone II</u> **<u>Patient Preparation Zone</u>** *· Waiting room, Changing room* *· Get a history from the patient* *· Unscreened patients can be present (patients screened for MRI)* *· Area unable for patients to move around freely*
			<u>Zone IV</u> **<u>Scan Room</u>** *· Unsafe objects cannot enter · Patient observed at all times* *· "Magnet is always on" sign · Direct supervision of MR technologist* *· MR Personnel 1 & 2 allowed to enter unsupervised (MR Personnel level 1 cannot accompany a patient.*

Unit of Measurements

Unit	Description	Measure	Example
dB/dx	Change in magnetic field strength over the change in distance	**Spatial Gradient Magnetic Field**	*400 gauss/cm* *4 Tesla/meter*
Gauss	Small unit of measurement	**Measures small magnetic fields**	*~0.5 gauss is the magnetic field felt on earth*
Tesla	10,000 gauss=1 Tesla	**Used to measure field strength**	*1.5 Tesla magnetic field*
I	The number of electrons flowing through a wire	**Amperes/Current**	*100A*
J	Amperes per square meter	**Current Density**	*Am^-2*
Φ	Tesla per m^2	**Magnetic Flux**	*T m^2*

Time-Varying RF Field

Unit	Description	Measure	Example
Watts/kg	Measures the amount of heating that a patient receives	**Specific Absorption Rate**	3 watts/kg
Hertz	The number of waveforms per second	**Frequency**	220Hz

Time-Varying Gradient Field

Unit	Description	Measure	Example
dB/dt	The change in magnetic field strength over a change in time	**Time-varying Magnetic Field**	*T/s*
Decibel	The magnitude of sound pressure	**Sound Pressure**	*60db*
NRR	The amount of sound reduction that an earplug or headset reduces	**Noise Reduction Rate**	*33NRR*
Milliseconds	Length of time	**Rise Time**	
mT/m	The magnetic field over distance	**Gradient Maximum Strength**	*35mT/m*
T/m/s	A magnetic field over a distance per second	**Slew Rate**	*150T/m/s*

Gadolinium Contrast Media

Unit	Description	Measure	Example
Milliseconds	Length of time	**Injection Duration**	30ms
ml/min/1.73m2	The amount of filtration of blood by the kidneys	**Globular Filtration Rate**	*60ml/min/1.73m2*
mL	Measurement of fluid	**Contrast Amount**	*20mL*
mmol/kg	Amount of a substance given	**Gadolinium Dose**	*1mmol/kg*
mL/second	An amount of a solution over a period of time	**Flow Rate**	*2mL/s*

Cryogen

Unit	Description	Measure	Example
Kelvin	A unit of temperature	Temperature of Cryogen	*4.2K*

Static Magnetic Fields

Unit	Description	Measure	Example
dB/dx	Change in magnetic field strength over the change in distance	**Magnetic Field**	*400 gauss/cm* *4 Tesla/meter*
dB/dx*B	Change in the magnetic field other the change in distance at a specific field strength	**Maximum Spatial Gradient/Force Product**	*70* $Tesla^2/m$

Gauss	Small unit of measurement	**Measures small magnetic fields**	*~0.5 gauss is the magnetic field felt on earth*
Tesla	10,000 gauss=1 Tesla	**Used to measure field strength**	*1.5 Tesla magnetic field*
I	The number of electrons flowing through a wire	**Amperes/Current**	*100A*
J	Amperes per square meter	**Current Density**	*Am^-2*
Φ	Tesla per m^2	**Magnetic Flux**	*T m^2*

Time-varying Gradient Field

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mL	Measurement of fluid	Contrast Amount	20mL
mmol/kg	Amount of a substance given	Gadolinium Dose	.1mmol/kg

mL/second	An amount of a solution over a period of time	Flow Rate	2mL/s

MR Personnel

	Responsible For:	Duties are to:
Patient	NA	NA
Non-MR Personnel	• Executing Level 2 Personnel Instructions. • The safety of themselves, ancillary staff, and the patient under the supervision of a Level 2 Personnel.	• Perform job duties while being mindful of MR safety concerns.
Level 1 MR Personnel	• Receiving basic MR safety training and maintaining it annually. • The safety of themselves in the MR environment.	• Perform job duties while being mindful of MR safety concerns.
Level 2 MR Personnel	• Receiving comprehensive MR safety training. • Annually take MR safety training. • The safety of themselves, ancillary staff, and the patient in the MR environment	• Understand MR safety and be able to contact individuals (MRSO/MRMD) for safety practices when necessary
Level 3 MR Personnel (MRSO)	Executing MR safety practices. o Aiding and take lead from the MRMD. o Educating ancillary workers in MR safety on a regular basis. o Consult the MRMD and/or MRSE for further advice. o Report MR Safety issues back to MRMD promptly. o Ensuring that Heads of Departments responsible for personnel involved in MR safety are informed and trained. o Maintain records of educated personnel. o Ensure purchasing, testing, and marking equipment policies are performed. o Providing safety advice on MR equipment and protocol modifications. Be always available to MR operators so that his/her facility is accessible.	• Enforce day-to-day MR safety policies and procedures • Ensure the MRMD procedures involving risk reduction and MR safety is followed and monitored. • Manage hazards from MR equipment and monitor measures taken to protect against hazards. • Providing the provision of MR safety education as directed by the MRMD.
MR Medical Director	• Identify MRSE and MRSO. • Create policies and procedures on MR safety and keep them up to date. • Ensure appropriate MR safety and quality assurance programs. • Ensure that MRSO and MRSE have record keeping of adverse events. • Ensuring appropriate ongoing risk assessment is conducted for the MR facility.	• Delegate's appropriate license and/or qualifications. • Perform root cause analysis on any MR safety adverse events.
MR Safety Expert	• Offering suggestions on MR protocol modifications. • Offering advice on MR Safety programs and MR Quality Assurance programs. • Providing an elevated level of advice on safety aspects of MR equipment. • Reporting back to MRMD.	• Offer suggestions on developing local rules and procedures for MR safety. • Provide safety advice on implants.

Limits

Static Magnetic Field

<u>Concerns</u>:

- Physical concerns
    - Translation / rotational force
- Electrodynamic forces
    - Flowing blood

Individuals exposed to up to 8T had no detrimental impacts on patients or fetuses.

- Occupational Exposure
    - ICNIRP
        - Head and trunk are limited to a magnetic flux density of 2T
        - Limbs are limited to a magnetic flux density of 8T
    - IEC
        - Head and trunk are limited to a magnetic flux density of 4T
        - Limbs are limited to a magnetic flux density of 4T
- General public
    - Any body part is limited to a magnetic flux density of 400mT

<u>FDA Limits</u>

- Individuals less than 1-month-old
    - Static magnetic field limit of 4T
- Individuals greater than 1-month-old
    - Static magnetic fields limit of 8T
- Any exposures to field strength greater than 4T require approval

Time-varying Gradient Field

Concerns:

- Induction
  - Electrical induction due to the principle of Faraday's Law
  - Stimulation
    - Cardiac fibrillation
      - Not reported
    - Diaphragm spasm
      - Cause difficulty breathing
    - Brain
  - Peripheral Nerve Stimulation
    - Limited to the comfort of the patient

IEC/FDA

- **Normal Operating Mode**
  - 80% of the maximum dB/dt exposure
    - =1.0 * rb(1+0.36/teff)
- **First Level Controlled Operating Mode**
  - 100% of the maximum dB/dt exposure
    - =0.8 * rb(1+0.36/teff)

*rb=20T/sec

*0.36ms=Peripheral Nerve Stimulation

FDA

- Sound Pressure Levels
  - 99dBA with hearing protection limit

Occupational Exposure

- **ICNIRP**
  - Restrictions are limited to 100 kHz
- **IEC**
  - Limits to peripheral nerve stimulation

Time-varying RF field

Concerns:

- **The deposit of heat**
  - **Measured in SAR**
    - **SAR is an estimate**
  - **Localized heating**
    - **Eyes, fetus, and testicles**
- **RF Burning**

FDA

- **Whole body exposure**
  - **Less than 1-degree Celsius increase**

FDA/IEC Whole Body Heating (averaged over any 6-min. period)

- **Normal Controlled Operating Mode**
  - Increase in core temperature to 0.5 degrees Celsius
  - Increase in whole body SAR to less than 2 W/kg
  - Head SAR over 6 min.
    - less than or equal to 3.2 W/kg
- **First Level Controlled Operating Mode**
  - Increase in core temperature to 1.0 degrees Celsius
  - Increase in whole body SAR to 4 W/kg
  - Head SAR over 6 min.
    - less than or equal to 3.2 W/kg
- **Second Level Controlled Operating Mode**
  - Increase in core temperature to greater than 1.0 degrees Celsius
  - Increase in whole body SAR to greater than 4 W/kg
  - Head SAR over 6 min.
    - Greater than 3.2 W/kg

Localized Transmit-Receive Coil Heating according to FDA/IEC (averaged over 10 grams for 6 min.)

- Normal Controlled Operating Mode
  - SAR equal to or less than 10 W/kg in the head or trunk (orbits limited to 1 degree Celsius)

- SAR equal to tor less than 20 W/kg in extremities
- First Level Controlled Operating Mode
  - SAR equal to or less than 20 W/kg in the head or trunk (orbit limited to 1 degree Celsius)
  - SAR equal to or less than 40 W/kg in the extremities
- Second Level Controlled Operating Mode
  - Greater than 20 W/kg for head and trunk
  - Greater than 40 W/kg for extremities

Time-varying RF field Continued…

Occupational Exposure

- **IEC**
  - 4 W/kg SAR
- **ICNIRP**
  - 0.4 W/kg SAR
  - 61 V/m
  - 0.16 A/m
  - 0.2 mT
  - 10 W/m^2

Pregnancy

Concerns:

- Static magnetic fields
  - No adverse effects noted to date
- Time-varying RF
  - Some effects have been noted at heating greater than 39 degrees Celsius
- Time-varying gradient field
  - Noise production is a concern
- Gadolinium contrast
  - Known to cross over the blood placenta barrier

ICNIRP

- **Patient with cardio circulatory impairment or pregnant patient**
  - Limit RF heating to less than .5 degrees Celsius
- **No gadolinium given**
- **Pregnant MR technologist cannot be in zone IV during data acquisition**

Manufacture Terminology

Static Magnetic Field

- Safe at 64MHz= Safe at 1.5 T
  - The center frequency for a 1.5 T is approximately 64 MHz
  - The center frequency for a 3 T is approximately 128 MHz
- Safe at 3 T = safe at only 3 T
- Safe up to 3 T= Safe at any field strength less than 3 T
- Safe up to 300 G/cm
  - This refers to the magnetic spatial gradient
  - A magnetic spatial gradient must be reviewed to determine if the patient can be scanned safely.
  - 300 G/cm = 3 T/m
- Orientation of the implant must be not aligned 90 degrees to the z-axis.
  - This means that an implant cannot be positioned in a way where translational force will not turn the implant off during acquisition.
    - A ferrous switch will interact with the magnetic field and turn off an implant prior to the exam.

- This object deflects 23 degrees at a magnetic spatial gradient of 7 T/m
  - This means that this object may be slightly attracted to the MR unit.
    - <45 degrees means that the deflection is insignificant
    - >45 degrees means that the deflection of the implant becomes more significant in risk

Time-varying Radiofrequency Field

- **Implant should not be exposed to more than 2.6 W/kg**
  - Since the limit for normal operation mode is 2 W/kg, we cannot scan in the first level-controlled operation mode.
- **This implant experiences heating of 5 degrees Celsius at 3 T with a 60mm length of wire.**
  - The operative report should give the length of the implant. If it is 60 mm, and the patient is exposed to RF, the patient will experience burning.
- **Implant should not be exposed to more than a whole-body SAR of 2.3 W/kg or a localized SAR of 4 W/kg.**
  - This means that we can scan in first level operation mode if we are using a transmit-receive coil and say in normal operation mode if we are using the body RF coil.

Time-varying Gradient Field

- **Do not expose the implant to more than 80% of the maximum threshold of the gradient coils.**
  - Thishe means that we must stay in normal operation mode.

Ways to Reduce Risk

Static Magnetic Field

- Utilize a Ferro detector for all staff and patients
- Properly mark items in accordance with the ASTM F2503
    - MR Safe
    - MR Conditional
    - MR Unsafe
- Provide proper level 1 and level 2 training for appropriate staff
- Have an accessible spatial magnetic gradient map of your MR unit

Time-varying RF Field

- Enter in a patient’s correct weight to get the most accurate SAR calculation
- Communicate with the patient during the exam
- Place a barrier between patient and gantry to eliminate proximity burn risk
- Place a barrier between bare skin contact spots to eliminate loop burn
- Use MR-compatible equipment in the MR suite
- Research all implants for manufacture instructions
- Consult with radiologists on questionable implants

Time-varying Gradient Field

- Communicate with the patient during the exam
- Avoid heavy gradient weighted sequences when possible

Gadolinium

Short term

- Have a contrast reaction plan and policy put in place

Long term

- Have labs drawn on patients that are 60 years or older, are diabetic, have hypertension, have renal or cardiac disease, or multiple myeloma to determine a GFR.
- Work with radiologists to make sure only patients who need a contrast agent for an appropriate diagnosis receive gadolinium.

Lowering Gradient Stimulation

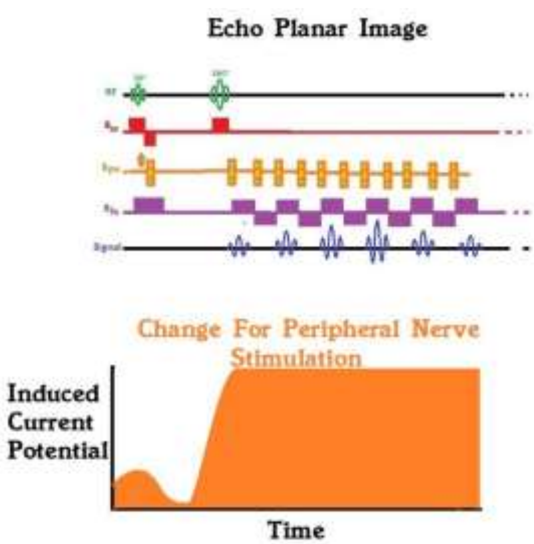
The potential graph below is purely theoretical. It is only shown to provide a visual representation of what is going on.

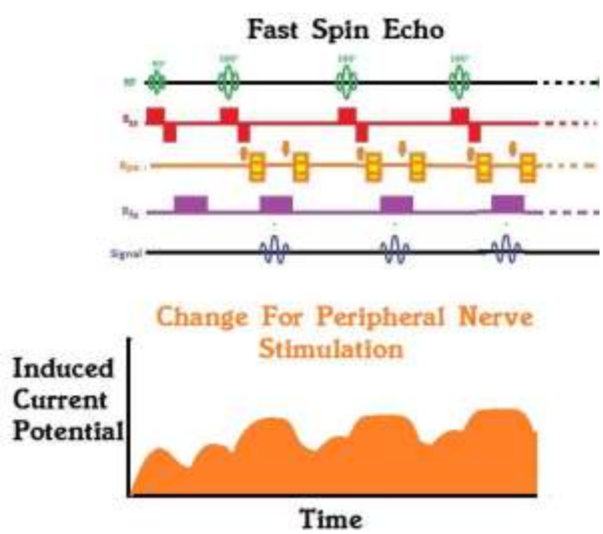
Peripheral nerve stimulation poses risks related to time-varying gradient fields. The following are some approaches that may be taken to lessen this.

Use Spin Echo Pulse Sequences

To image our subject, we can employ a variety of pulse sequences. Heavy gradient activation sequences can enhance stimulation in our patients. The echo planar picture, which employs numerous gradient activations to swiftly fill a K-space, is an example of this.

To excite hydrogen in our patient, a 90-degree RF pulse is employed, and instead of applying massive gradient activations to refocus hydrogen nuclei (as in gradient echo sequences), a 180-degree RF pulse is used. This means that there will be fewer opportunities for stimulation.

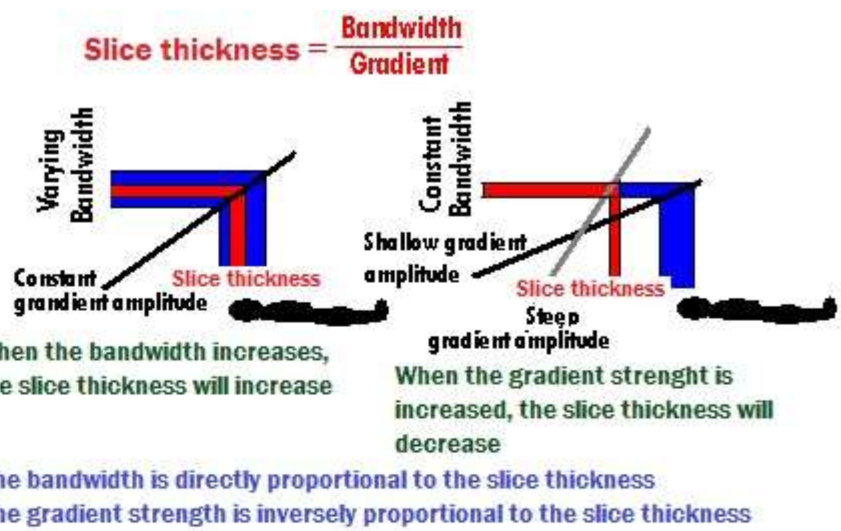




Use Thicker Slices

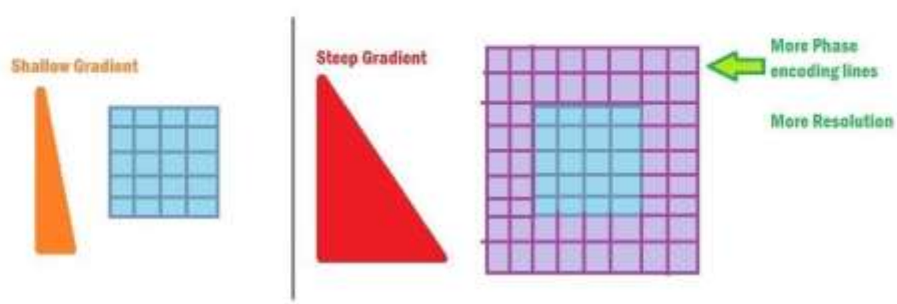
We can create narrower slices by employing a steeper slice selection gradient. This will cause a significant shift in magnetism in our patient's peripheral. According to Faraday's Law of Induction, conductive materials exposed to changing magnetic fields will induce a current. This rises when magnetic fields get bigger and more rapidly changing.

Because higher gradient activations may be employed with narrower slices, stimulation has a larger probability of occurring.



Use a Smaller Image Matrix

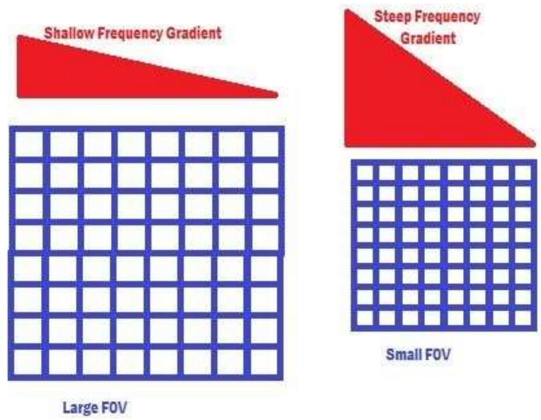
A huge picture matrix increases the number of lines of K-space that we fill around it. This signifies that our image will have a higher resolution. We need to apply a higher phase encoding gradient to fill these additional lines of K-space. This will stimulate the peripheral nerves. As a result, employing a smaller picture matrix will mitigate this impact.



Use a Larger Field of View

A lower FOV will need a steeper frequency encoding gradient. This will stimulate the peripheral nerves.

We can reduce this impact by employing a bigger FOV.



Note

Changing these factors will not impose PNS on our patients. To make a difference in the amount of stimulation experienced, it must be combined with rapidly changing gradients. These modifications in methodology will allow us to start pushing the limitations of our gradient system hardware to its fullest.

Lowering Patient Heating

The patient SAR graphs depicted here are hypothetically calculated. They are just there to provide a visual representation of what is going on.

In individuals who have difficulty controlling their body temperature, it is critical to minimize the specific absorption rate. The following are some of the most efficient methods for lowering the specific absorption rate.

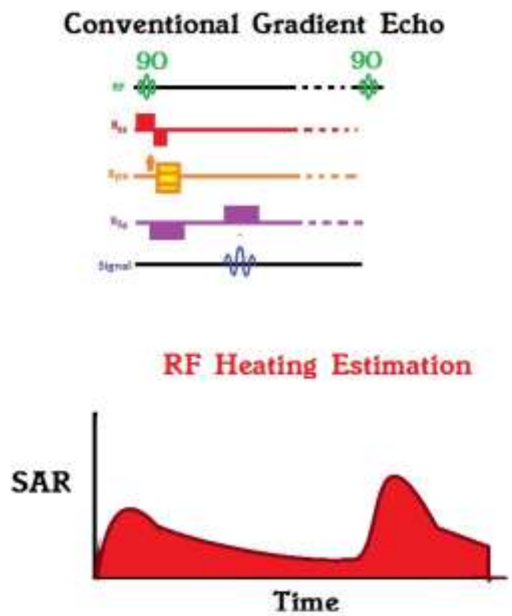
Use a Gradient Echo Pulse Sequence

The sort of pulse sequence we select has a significant impact on the quantity of energy delivered to our patients. Use sequences with a high number of RF pulses or pulses that tilt nuclei away from longitudinal magnetism. A 90-degree RF pulse is followed by one or more 180-degree RF pulses in spin echo pulse sequences. A 180-degree RF pulse has four times the energy of a 90-degree RF pulse. Because spin echo sequences deposit the most energy to our patients, they should be used with caution while lowering patient heating. The spin echo sequence has numerous advantages over conventional pulse sequences. However, when a spin echo sequence is required, alternative methods of minimizing heating should be adopted.

A gradient echo sequence can be employed if possible. The advantage of these pulse sequences is that they employ fewer RF pulses. The majority of these sequences employ one RF pulse per TR. To refocus our hydrogen, we employ gradient activation. Here are some of our alternatives when employing pulse sequences, which are less likely to cause heating than spin echo sequences.

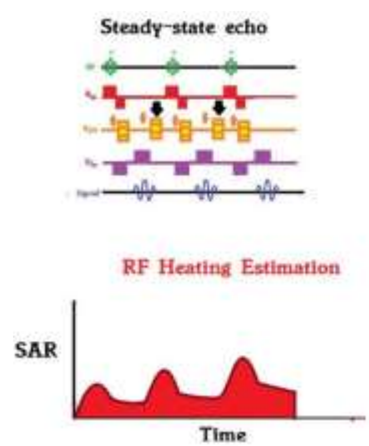
Conventional Gradient echo

The traditional gradient echo employs a 90-degree RF followed by a 180-degree RF. This means that we can provide less warmth to our patients than a spin echo sequence.



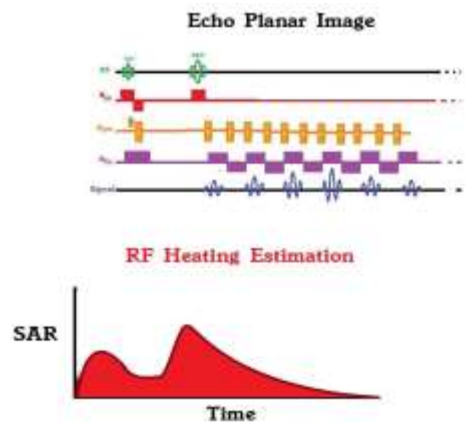
Steady-State Gradient Echo

A flip angle of fewer than 90 degrees is used in steady-state gradient echo. This means that our patients will receive less RF energy. The difficulty with these sequences is that we employ a very short TR, which can lead to a situation in which the patient does not have enough time to thermoregulate their temperature, which can lead to heating. This short TR does not create substantial heating due to the relatively modest RF pulse employed.



Echo Planar Imaging

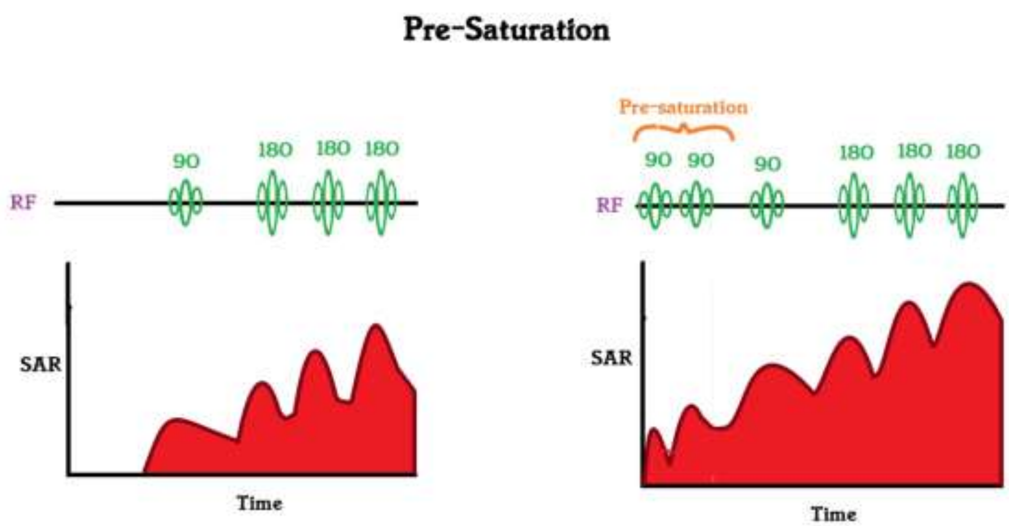
The echo planar image is most well-known for its application in diffusion-weighted imaging, perfusion imaging, and functional MRI. To cover the whole k-space, this sequence will require an RF pulse and multiple fast-changing gradient activations. This pulse sequence has advantages and cons, and it is less diversified than other pulse sequences. This implies that it can only be utilized for diagnostic purposes with diffusion-weighted imaging, perfusion imaging, or functional imaging.



Spin echo sequences are essential and should be employed. Gradient echoes can be put between spin echo sequences to minimize SAR. This will allow the body to control its own temperature.

Avoid Chemical Shift Pre-saturation (Fat Saturation)

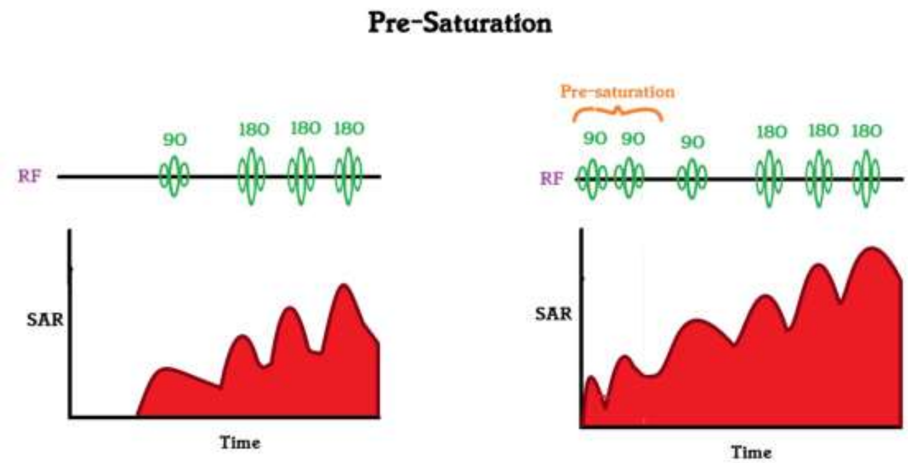
For a fat saturation to do its job, it needs to identify a patient's chemical shift and suppress the frequencies associated with fat. To do that, one or many 90-degree RF pulses are delivered to the



area being imaged prior to the TR localizing the fat frequencies. This will cause our patients to get hotter.

Avoid Spatial Pre-saturation (Sat Band)

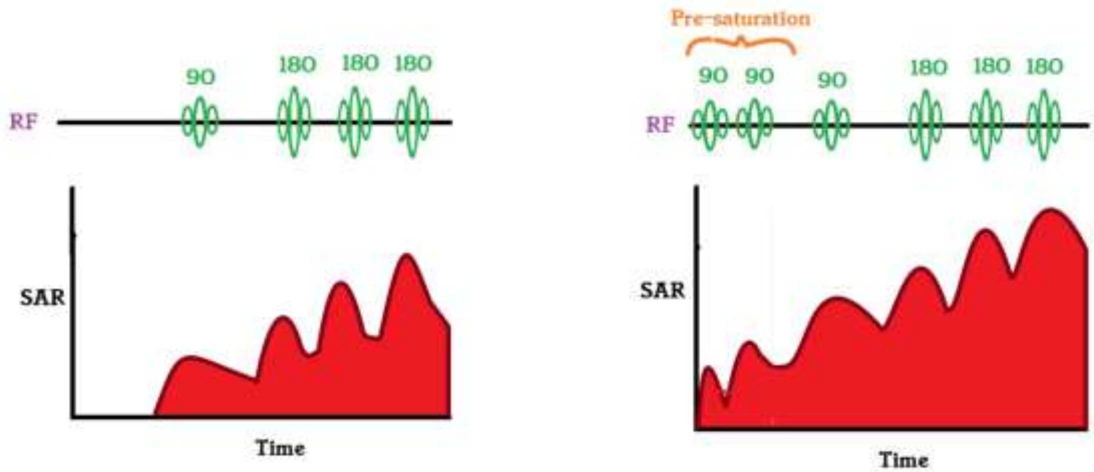
To get a fat saturation to work, we need to identify the region of tissue we want to inhibit and apply a band over it. To do this, one or more 90-degree RF pulses are provided to the imaged region before the TR localizing the sat band area. This will cause our patients to get hotter.



Avoid Magnetic Transfer Compensation

MTC aims to suppress bound protons in our picture. To do this, one or more RF pulses at a specified frequency are supplied to our patient. This will cause our patients to get hotter.

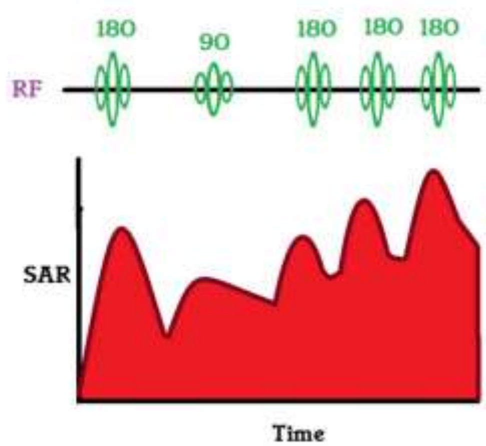
Pre-Saturation



Avoid Inverse Recovery Sequences

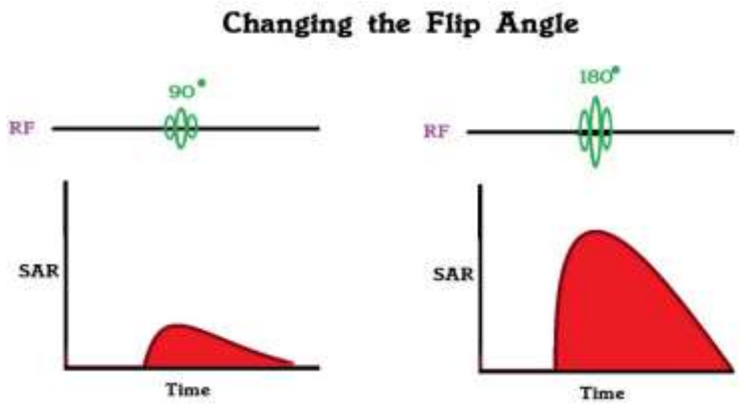
A spin echo or a gradient echo can be used to achieve the inverse recovery procedure. A 180-degree RF pulse is utilized before our original 90-degree RF pulse for this to operate. The inverse time is the time that we wait between our 180-degree RF pulse and our 90-degree RF pulse. This additional 180-degree RF pulse may cause our patient to overheat. However, this sequencing has numerous advantages for detecting disease in our patients. This suggests that this sequence outperforms other picture weighting algorithms, including fat saturation techniques.

Inverse Recovery



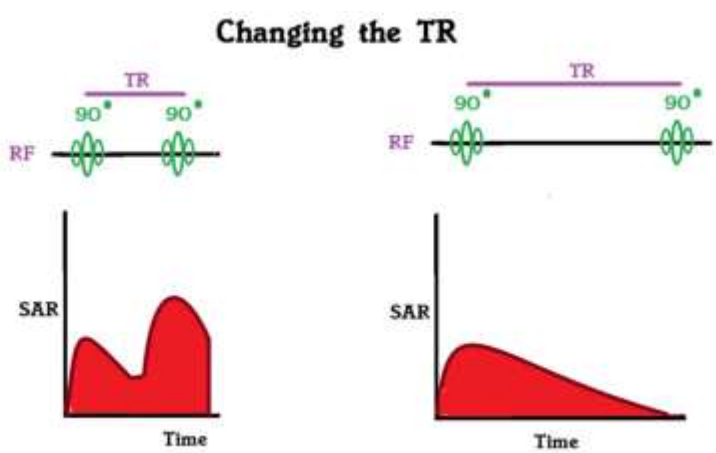
Decrease Flip Angle

We know that the energy of our RF pulse rises in quadratic proportions. This indicates that a 180-degree RF pulse has four times as much energy as a 90-degree RF pulse. We can limit patient warmth by using an RF pulse that is smaller than 90 degrees. This, however, has the potential to influence our image contrast, so we should proceed with caution while modifying this value.



Increase Repetition Time (TR)

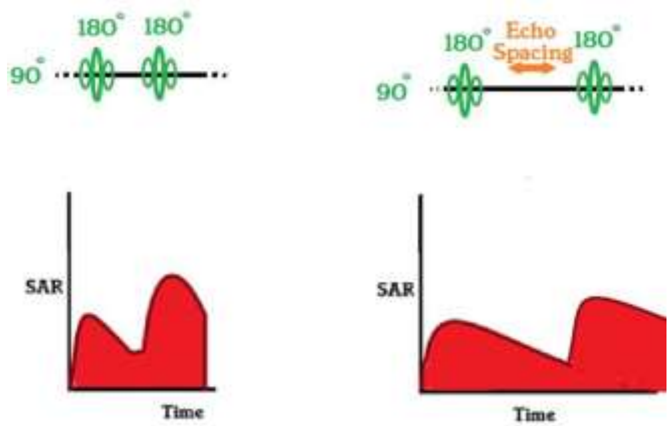
The TR is the time between one RF pulse and the next. The longer our TR, the more time our patient has to thermoregulate themselves. We do know, however, that a prolonged TR promotes PD and T2 weighted imaging. When it comes to obtaining T1 weighted pictures, this approach is not very productive.



Increasing the echo spacing

This signifies that the spacing between RF pulses is growing. Specifically, extending the spacing between 180-degree RF pulses while employing a spin echo sequence. This approach will increase the possibility of thermoregulation in our patients.

This can be accomplished by reducing the field of vision, boosting frequency encoding, or decreasing bandwidth.

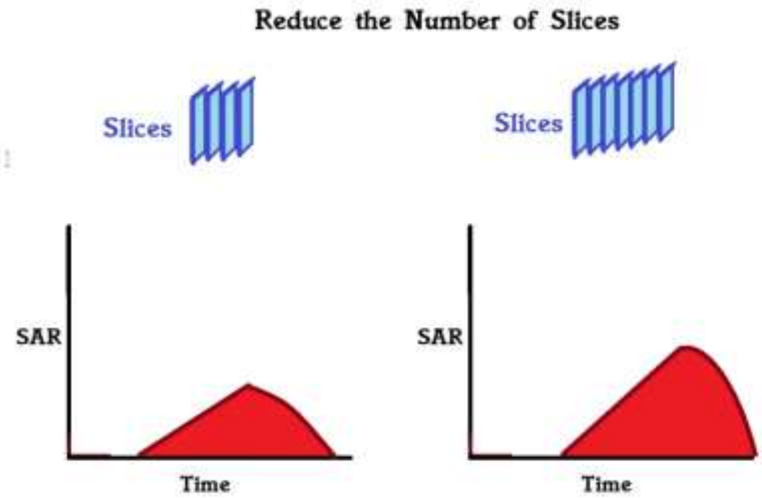


Change Pulse Mode

To vary the way an RF pulse is transmitted to our patient, we can change the pulse mode. Whisper mode, normal mode, and low SAR mode are all examples of pulse mode types.

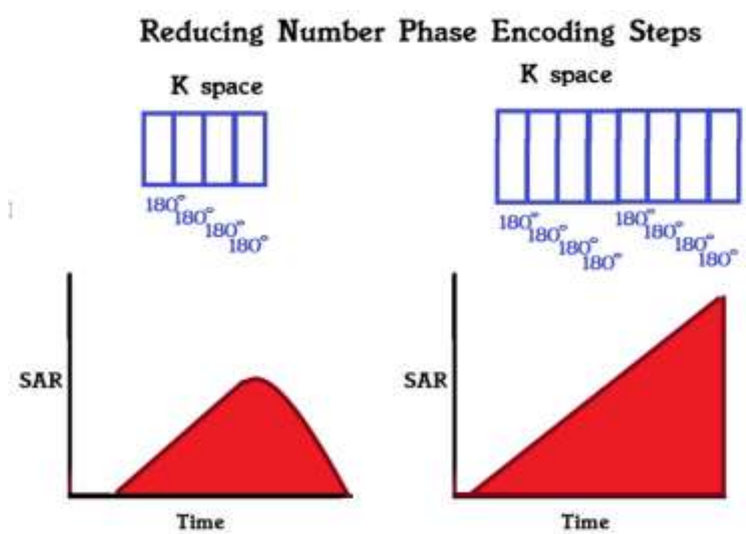
Reduce Slices

We lower the number of RF pulses required to fill additional K-spaces by decreasing our slices. This will transfer less energy to our patients, resulting in decreased patient heating.



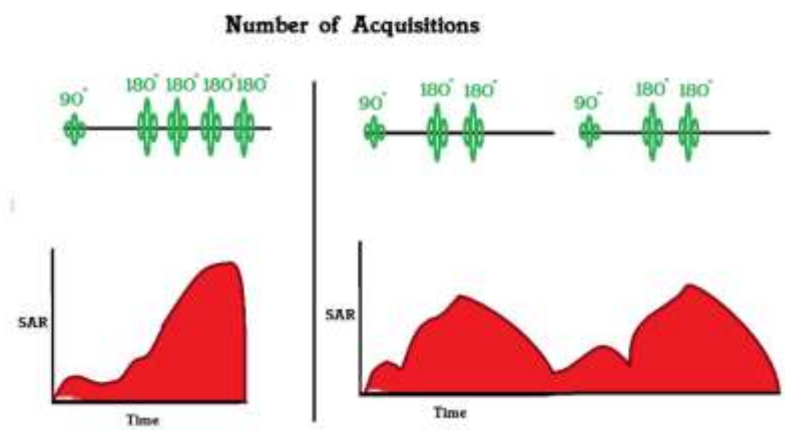
Reduce Image Matrix

We may minimize the number of lines of Kspace that must be filled by lowering the phase resolution in our image matrix. This implies fewer refocusing pulses/TR cycles will be required. This has the potential to lower patient warmth.



Increase Concatenations / Number of Acquisitions

The number of acquisitions or concatenations determines the number of echoes captured per TR. We reduce the number of echoes captured with each TR by raising this value. This gives our patients more time to thermoregulate.



Use Parallel Imaging

Parallel imaging will help us to cut scan duration while increasing the signal-to-noise ratio (SNR). It does this by simultaneously filling our K-space with many coil components. The number of coil elements in the phase direction determines this. Parallel imaging with multiple coil components in other directions may also be possible with new approaches.

We can use less RF to fill our Kspace since we get more out of each RF pulse when we utilize this strategy. This will help to keep the patient cool.

Decrease Number of Averages

The number of averages will fill our K-space as many times as the factor we have chosen. This implies we'll have to employ more RF pulses to replenish our K-space, which will raise patient heating.

Reduce the Number of Signal Averages