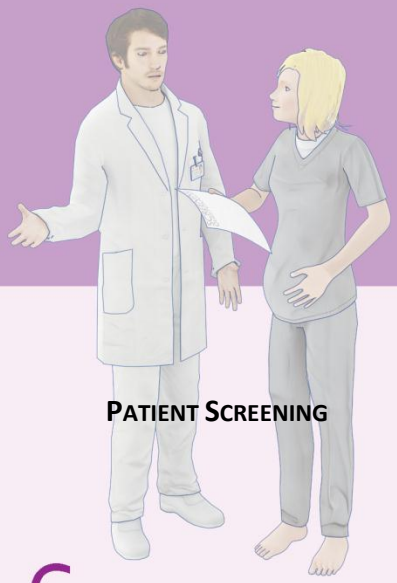
Safe and comfortable examination of patients is a key priority for operators.

Click the safety area or scroll to read more.

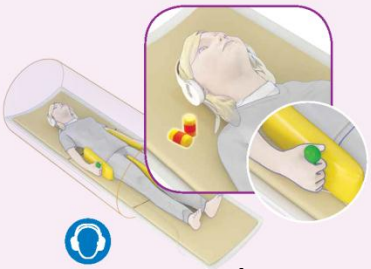


PATIENT SCREENING

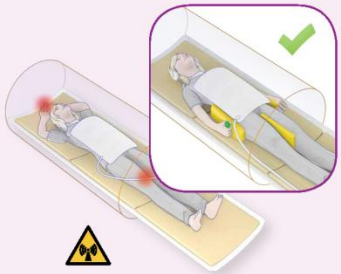
MR the safe way

PROJECTILE EFFECTS

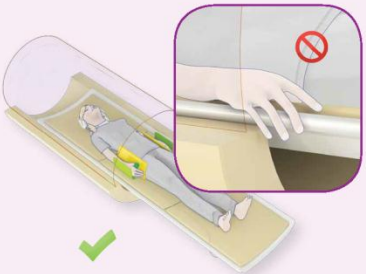
IMPLANTS



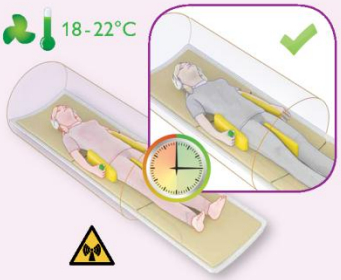
NURSE CALL/HEARING PROTECTION



PATIENT POSITIONING



FINGER PINCHING



RF ENERGY EXPOSURE

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About this reading

Rationale for this reading

Safe and comfortable examination of patients is a key priority for operators.

In this eReading we elaborate on the basic safety guidelines as summarized in the ‘MR the safe way’ poster. Neither the poster, nor this eReading is a replacement for the Instructions for Use. You must also read and understand Chapter 2 of the Instructions for Use. If any part is unclear, please contact your local safety officer, physicist or applications specialist.

Training Objectives / Expected outcome

After completing this eReading, you should be able to:

- Describe the five common hazards associated with the MR scanner
- Describe the method for screening patients prior to the MR exam
- Describe the six basic guidelines for safe operation of the MR scanner
- Operate the MR scanner in a safe way

Responsibilities / Tasks

This eReading complements the “MR the safe way” poster.

Target audience

This eReading has been created for MR operators.

Topics

Click a topic to read more:

Click here to view graphical navigation.

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Introduction

There are potential risks in the MR environment, not only for the patient but also for the accompanying family members, attending health care professionals such as security or housekeeping personnel, firefighters, police, etc., and others who find themselves in the magnetic fields of MR scanners.

There have been reports detailing Magnetic Resonance Imaging (MRI) adverse incidents involving patients, equipment, and personnel. Most reported cases of MR-related injuries are the result of failure to follow safety guidelines. Preventing these incidents is a key priority for operators. Re-enforcing and providing training on basic safety guidelines to all MR personnel should be done continuously.

This eReading module provides guidance for preventing injuries in MRI suites. The order of these instructions is arranged around a routine MRI examination, similar to the “MR the safe way” poster. Content wise this eReading is in line with the “ACR Guidance Document on MR Safe Practices 2013” which contains the industry standards for safe and responsible practices in clinical and research MR environments.

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(Patient) Screening

Basic safety guidance:

Screen all patients for contra-indications and increased risks.

Why screening?

Thorough and effective screening of patients and other people before entering the MR examination room reduces the likelihood of an adverse event. The establishment of such a screening procedure is one of the most critical components of an MR safety program.

This section explains how to screen all those preparing to undergo MR procedures or to enter the MR examination room.

Known hazards associated with MRI include, but are not limited to:

- Projectile Effect (Static Magnetic Field issue)
- Twisting (Static Magnetic Field)
- Hearing Loss (Gradient Magnetic Field)
- Patient Heating (Radio Frequency Electromagnetic Field)
- Moving Mechanical Parts (Patient Support)

Screening can reduce the chance that somebody is harmed by one of these hazards.

Patient screening is done:

1. When an exam is considered
2. As part of the scheduling process
3. Prior to entering the exam room
4. During the examination

All people who enter the MR examination room, with exception of MR authorized personnel, must be screened every time prior to entering the exam room.

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1. Preliminary screening

Preliminary screening of patients starts when an MRI examination is considered by a referring physician. The goal is to ascertain whether the patient has any implant or medical condition which may be contraindicated for the MR procedure.

In general, an MR examination is contraindicated for patients with electronic or electronically conductive implants of metals, especially those containing ferromagnetic foreign matter. Patients at risk for thermal injury must also be identified during screening. These patients require special precautions.

2. Screening during scheduling of patients

Comprehensive screening must be done when the patient has been referred for an MRI examination. A printed form must be given to the patient, or patient representative, and used to document the screening. The printed screening form can be given by the referring physician or MR employee responsible for scheduling patients. A review of the information must be done by MR authorized personnel (safety trained MR operator and/or MR physician).

A verbal interview should be conducted to verify the information on the form and allow discussion of questions and concerns. You should conduct this interview during the scheduling process to avoid disruptions of the schedule.

The information provided in the screening form and interview may lead to further investigations and specific precautions by the MR operator.

3. Screening prior to entering the MR room

All people who enter the MR examination room, with exception of MR authorized personnel, must be screened using a MR safety screening form.

Patients may have completed such a form in preparation for the examination. Other people requesting entry must be screened by MR safety trained MR authorized personnel. Proper screening for individuals involves the use of a screening form to document the screening procedure, a review of the information on the form, and a verbal, face to face, interview to verify the information on the form and to allow discussion of any question or concern that the individual may have before permitting entry to the MR environment. Forms must be signed by the person who is performing the screening and by the individual requesting entry.

The information provided may require further investigations or prevent people from entering the MR room.

4. Continuous surveillance during the examination

The MR operator must maintain continuous contact with the patient in the MR room either directly or via an observation monitor and intercom.

All patients must receive a nurse call (squeeze ball) and be instructed to notify the MR operator immediately if any discomfort arises during the examination.

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Periodically talking with and listening to the patient via the intercom is a way to maintain continuous contact. Specific attention is necessary during examinations in which the table will move.

Patients at risk, especially those who cannot sense local heating or cannot attract the operator's attention, must regularly be inspected for excessive sweating or skin reddening. If excessive sweating or skin reddening is observed, remove the patient from the scanner and cool the affected area.

Patients at risk for thermal injury

Patients at risk for thermal injury must only be scanned after a clinical judgment is made as to the patient's benefit versus potential risk and appropriate precautions must be taken.

Patients at risks are patients with conditions which effect the thermoregulation, are unable to sense local heating or cannot attract the operator's attention. Known medical conditions include, but are not limited to:

- Pediatric, pregnant and elderly patients
- Unconscious, anesthetized or sedated patients
- Patients with impaired ability to perspire; for example, due to age, overweight, diabetes, or hypertension
- Patients with loss of feeling in any body part; for example, paralysis of arms or legs
- Patients under specific drug regimes that may affect thermoregulatory capabilities, such as diuretics, tranquillizers or vasodilators
- Patients who are very sick, confused, or may be unable to sense or communicate heat sensations.
- Patients with fever
- Patients who are thermally insulated (e.g. in a gypsum cast)
- Patients with whom no reliable communication can be maintained

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Preparing to scan patients at risk

If a clinical decision is taken to scan a patient at risk, appropriate precautions must be taken; these include, but are not limited to:

- Provide medical supervision during the examination
  - Monitor vital parameters
  - Inspect the patient between scans for excessive sweating or skin reddening
    - If excessive sweating or skin reddening is observed, remove the patient from the scanner and cool the affected area
- Limit the Whole Body SAR
  - Avoid scanning in the first level controlled mode, i.e. avoid scanning with Whole Body SAR values greater than 2W/kg
  - Limit the Whole Body SAR to maximum 1 W/kg whenever possible
- Keep the total examination time to as short as possible
- Keep total scan SED below 3.5 kJ/kg

Patients with MR conditional implants

Patient with implants must only be scanned after a clinical judgment is made as to the patient's benefit versus potential risk and appropriate precautions must be taken.

In general, an MR examination is contraindicated for patients with electronic or electronically conductive implants of metals, especially those containing ferromagnetic foreign matter.

Some implants (devices) are labeled MR conditional by the implant manufacturer.

If the clinical decision is taken to scan the patient with an MR conditional implant or device, it is the responsibility of the MR operator to obtain the appropriate conditions for MR scanning.

Preparing to scan patients with MR conditional implants

- Obtain the specific conditions under which MR scanning is permissible for a given device.
  - Obtain the original labeling of the MR conditional implant or contact the implant manufacturer.
  - Do not scan if the conditions to scan are not known.
- Compare the implant labeling information with information provided by Philips in the user documentation (Instructions for Use and Technical Description) regarding the specific MR System to determine whether all conditions can be adhere to.
  - Do not scan if the conditions to scan cannot be met.
- It can be a time consuming task to obtain the implant labeling, you should therefore collect it well before the arrival of the patient.

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Projectile Effects

Basic safety guidance:

Do not bring ferromagnetic objects into the examination room. The attraction by the magnet may lead to serious or fatal injury to the patient or other people in the area of the scanner.

Strong magnetic field

The magnet in an MRI examination room is always on and is referred to as the static magnetic field.

This static magnetic field (B_0) is very strong. In the center of the magnet bore, the static magnetic field is typically 1.5 Tesla (T) or 3T which is approximately 30,000 or 60,000 times stronger than the earth's magnetic field (which is ~0,05mT). The strength of the magnetic field drops off rapidly with distance away from the scanner. The resulting magnetic field outside the scanner is called the fringe field.

Ferromagnetic objects in the fringe field are attracted by the static magnetic field with very strong forces at high speed. This is called the projectile effect and is the primary hazard associated with the static magnetic field.

An item as small as a paper clip or hair pin can reach speeds of up to 65 km/h (40 mph) when pulled into a 1.5T magnet and can cause serious damage or injury.

The larger or heavier the object, the stronger the (translational) forces involved as attraction is roughly proportional to the mass of the object.

The attraction force increases rapidly within a strong field gradient; i.e. in the fringe field when you approach the magnet. An object that does not appear to demonstrate ferromagnetic properties may suddenly be pulled into the magnet as you take one step further.

To prevent injury due to projectile effects:

- Patient screening and controlled access prevent accidents related to the static magnetic field.
- Mark the entrance of the controlled access area with a Safety Marking Plate showing the appropriate safety symbols.

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Examples of a Safety Marking Plate

Explanation of the used icons:

No access for people with active implantable medical devices (AIMD)

No access for people with metallic implants

No access for people with brain clips or artificial eyeballs

Access only for approved devices

No ferromagnetic articles allowed

No ferromagnetic tools allowed

No credits cards or phones allowed

No large ferromagnetic objects allowed

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Implants

Basic safety guidance:

Adhere strictly to the conditions as specified by the implant manufacturer. If conditions are not known, do not scan.

Twisting force

The static magnetic field exerts a torque or twisting force on ferromagnetic objects. A ferromagnetic object will attempt to align its long axis with the magnet's field lines. The torque increases with field strength and is considerably greater than the mass of the object. The ability to twist and displace objects is a major hazard associated with the static magnetic field.

Switching fields

In addition to the forces and torques caused by the main static field (B_0), implants will experience switching gradient fields and transmitted RF fields (B_1). Gradient fields provide the relative small magnetic field variations needed for the localization of the MR signals emitted by the human body. The transmitted RF field is primarily responsible for the signal excitation part of the MRI process.

Potential hazards are heating of the components or device malfunction. Absorption of RF energy may result in excessive local heating. MR examinations are therefore, generally speaking, contra-indicated for patients with implants.

Device labeling

Certain implantable medical devices are labeled "MR Conditional" by the implant manufacturer. For such devices, the general contra-indications may not be applicable in its entirety. If the clinical decision is taken to scan the patient with an MR conditional implant or devices, the specific conditions under which MR scanning is allowed must be obtained and compared with system specific information provided by Philips in the user documentation (Instructions for Use and Technical Description).

MR safety classification for devices:

MR safe **MR Conditional** **MR Unsafe**

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To prevent injury to patients with implants:

- Patient screening and controlled access prevent accidents related to implants.
- Obtain the specific conditions under which MR scanning is permissible for a given device
    - Do not scan if the conditions to scan are not known
- Adhere strictly to the conditions set in the implant labeling information.
    - Do not scan if the conditions cannot be met.

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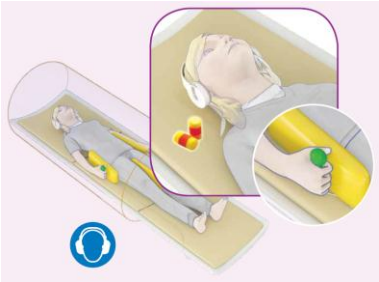
Nurse Call / Hearing Protection



Basic safety guidance:

Use the nurse call with every patient and give instructions about its use. Provide appropriate hearing protection for every patient and anyone else in the room.

Hearing protection

The MR scanner is very noisy during operation. The noise is produced by the switching gradient fields causing a change in the Lorentz force experienced by the gradient coil. Without hearing protection, noise levels may be high enough to cause discomfort or result in temporary or even permanent loss of hearing

Provide hearing protection:

- Earplugs and/or a headset must be worn by the patient and anyone else in the room during scanning.

Nurse call communication

It is advised to communicate when the system gradients are off. Because of acoustic noise levels in the examination room verbal communication with the patient may be impaired.

Communicate with patient:

- Give each patient a nurse call (squeeze ball) and verify it is functioning.
- Instruct patients how to notify the MR operator immediately if any discomfort arises during the examination.
- Periodically visually inspect patients at risk, especially those who cannot reliably use the nurse call or respond verbally.

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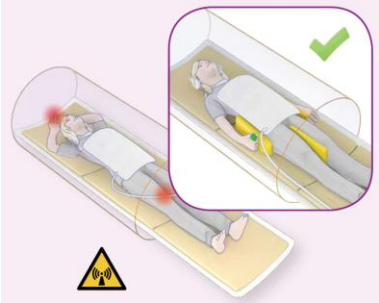
Patient Positioning



Basic safety guidance:

Prevent contact between body parts or skin and coil cables. Verify clearance between body parts and the bore wall.

Induction of electrical currents in the human body

The transmitted RF field is primarily responsible for the signal excitation part of the MRI process. The time-dependent nature of this RF field also results in the induction of electrical currents in the body. These currents flowing through the electrically conductive tissue of the human body result in heat dissipation.

The transmitted RF energy and the associated heat dissipation is a potential hazard for all patients. The risk of RF energy related injuries is higher in patients with a restricted thermoregulatory capacity, for patients with whom no reliable communication can be maintained and for those patients who are inadequately positioned.

Preventing contact between body parts

A body part touching another body part (or a body part touching a coil cable or the bore wall) can form a loop through which a current can flow. The formation of a high-frequency current loop in the patient's body may cause burning at the point of (full or partial) contact.

Loops must be avoided.

Anything larger than the index finger and thumb creating a loop is classified as a large loop. The larger the loop, the greater the risk is for a burn to occur.

To prevent contact between body parts:

- Always position the patient so that hands, arms and legs do not touch.
- Avoid skin-to-skin contact which creates a current loop. Current loops can lead to tissue heating and peripheral nerve stimulation.
- Verify that a distance of 2 cm between body parts is maintained during scanning.
- To provide sufficient distance (2 cm) between body parts, padding from the Philips' accessory set can be used at places where body parts potentially touch and close a loop.
- When using alternative padding, verify that it is thick enough, 2 cm, also when compressed, and made of non-conductive material; for example, linen, cotton or dry material that is permeable to air.
- The applied padding must never obstruct the patient airflow in the bore.
- Any added insulation (such as blankets) must be removed as it may prevent satisfactory dissipation of body heat.

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Preventing contact between skin and cables

Cables can form a loop with themselves, with other cables, or by touching the patient or bore wall.

Cable loops must be avoided. Inappropriately routed cables can lead to excessive heating of the cables which may result in burns upon contact to the patient's skin.

To prevent contact between skin and cables:

- Always position the cables straight, no loops, no twisting. Keep the cables parallel to axis of the bore with 2 cm distance from the bore wall and patient's skin.
- Use padding from the Philips' accessory set to provide sufficient distance (2 cm) between coil cable and body parts, or coil cable and bore wall.
- When using alternative padding verify that it is thick enough, 2 cm, also when compressed, and made of non-conductive material, e.g. linen, cotton or dry material that is permeable to air.

Verifying clearance between body parts and the bore wall

Current loops can be formed when the patient touches the bore wall and must be prevented. Additionally, the airflow is disturbed or blocked when the bore is touched. Clearance is required to allow for active cooling of the patient by means of the ventilation.

Precautions to take when touching the bore wall cannot be prevented:

- If touching of the bore wall cannot be prevented, other types of examinations must be considered.
- If a clinical decision is taken to scan a patient who cannot be positioned without touching the bore wall, medical supervision during the examination must be provided.
    - Monitor vital parameters.
    - Inspect the patient between scans for excessive sweating or skin reddening
        - If excessive sweating or skin reddening is observed, remove the patient from the scanner and cool the affected area
- Limit the Whole Body SAR
    - Avoid scanning in the first level controlled mode, i.e. avoid scanning with Whole Body SAR values greater than 2W/kg
    - Limit the Whole Body SAR to maximum 1 W/kg whenever possible
- Keep the total examination time to as short as possible
- Keep total scan SED below 3.5 kJ/kg
- A small rolled towel (compressed > 5mm thickness) can be used between patient and bore wall.

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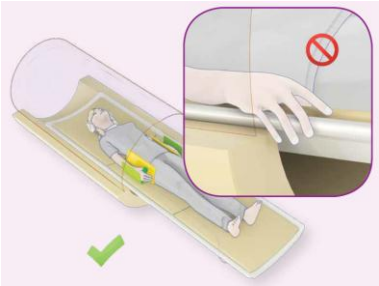
Finger Pinching



Basic safety guidance:

Verify that patient's hands are on the tabletop before moving the tabletop into the magnet.

Moving parts

During movement of the tabletop, fingers can get caught between the tabletop and the system covers.

To prevent finger pinching:

- The arm supports of the accessory set can be used to avoid finger pinching. The arm supports prevent the patient from grabbing around the table sides avoiding finger pinching during tabletop movement.

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RF Energy Exposure

Basic safety guidance:

Warming sensations are to be expected in MRI, they are caused by the RF power needed to acquire images. Take appropriate precautions to prevent heat dissipation from becoming a hazard.

Heat dissipation

The transmitted RF field is primarily responsible for the signal excitation part of the MRI process. The time dependent nature of this RF field also results in the induction of electrical currents in the body. These currents flowing through the electrically conductive tissue of the human body result in heat dissipation.

The transmitted RF energy and the associated heat dissipation is a potential hazard for all patients. Tissue heating can occur if the patient's body cannot dissipate the generated heat quick enough. The risk of RF energy related injuries is higher in patients with a restricted thermoregulatory capacity.

Preventing high RF energy exposure

During an MRI examination, RF energy is transferred to the body resulting in warming sensations. Limiting the amount of RF energy (SED) delivered to the patient, limits the temperature rise in the patient.

SED is the Specific Energy Dose expressed in kJ/kg. SED is determined by the SAR and scan duration.

SED = Whole Body SAR x scan time.

SAR is the rate of delivered energy expressed in W/kg. Patient temperature rise is proportional to SED. The SED is an indicator for patient comfort: in general, a delivered SED value > 3.5 kJ/kg may be uncomfortable for some patients.

Patient comfort during scanning is affected by the condition of the patient and must be taken into account. A rise in body temperature can be a hazard to a patient with restricted thermoregulatory capacity.

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To limit SED:

- Avoid scanning in the first level controlled mode, i.e. avoid scanning with Whole Body SAR values greater than 2W/kg
- Limit the Whole Body SAR to maximum 1 W/kg whenever possible
- Limit the scan duration
- Keep the total examination time to as short as possible
- Keep total scan SED below 3.5 kJ/kg

Keeping the room temperature between 18-22°C/ 65-72°F

Radiation is the most important heat transfer mechanism at ordinary room temperatures and is effective for losing the heat produced by the basal metabolism in healthy people. Other standard heat transfer mechanisms are conduction and convection.

With an increased room temperature, the body tries to dissipate the heat mainly through the mechanism of evaporation of perspiration as the standard heat transfer mechanisms are not effective.

Increased humidity levels also affect the patient's ability to dissipate heat.

To keep the room temperature and humidity levels:

- Monitor and maintain the room temperature (18-22°C/ 65-72°F).
- Monitor and maintain the humidity levels, it must be kept below 70%.

Use adequate patient cooling

Ventilation of the patient space supports the cool down mechanism of the body. An appropriate level must be selected and the airflow in the bore must not be obstructed.

- Verify that airflow in the bore is not obstructed.
- Remove any added insulation such as blankets or warm clothing. Insulation is interfering with the capability to dissipate heat.

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For further reading

1. *ACR Guidance Document on MRI Safe Practices* 2013
2. *VHA HANDBOOK* 1105.05, 2012

Terminology used in this document:

MR operator: MR authorized personnel= level 2 MR personnel

MR authorized personnel: level 2 MR personnel (E.g. safety trained and certified operators and physicians)

Level 2 MR personnel, see *ACR Guidance* document

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Printed form: Sawyer-Glover and Shellock developed a screening form for a patient which is used by many MRI facilities. It is titled: “Magnetic Resonance (MR) Procedure Screening Form for Patients” and created in conjunction with the Medical, Scientific, and Technology Advisory Board and the Corporate Advisory Board of the Institute for Magnetic Resonance Safety, Education, and Research (IMRSER). You can download this form from the MR safety web sites, www.IMRSER.org and www.MRIsafety.com.

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A screening form was created specifically for individuals that need to enter the MR environment and/or MR magnet room. This form, entitled, “Magnetic Resonance (MR) Environment Screening Form for Individuals” may be obtained from the web sites, www.IMRSER.org and www.MRIsafety.com.

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Thermoregulation is the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different.

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MR Conditional: Devices labeled as MR conditional must pose no known hazards in specified MR environments complying with specified conditions of use as determined by the device manufacturer. For patients with implants that are labeled as MR conditional, consult the implantable device's labeling.

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