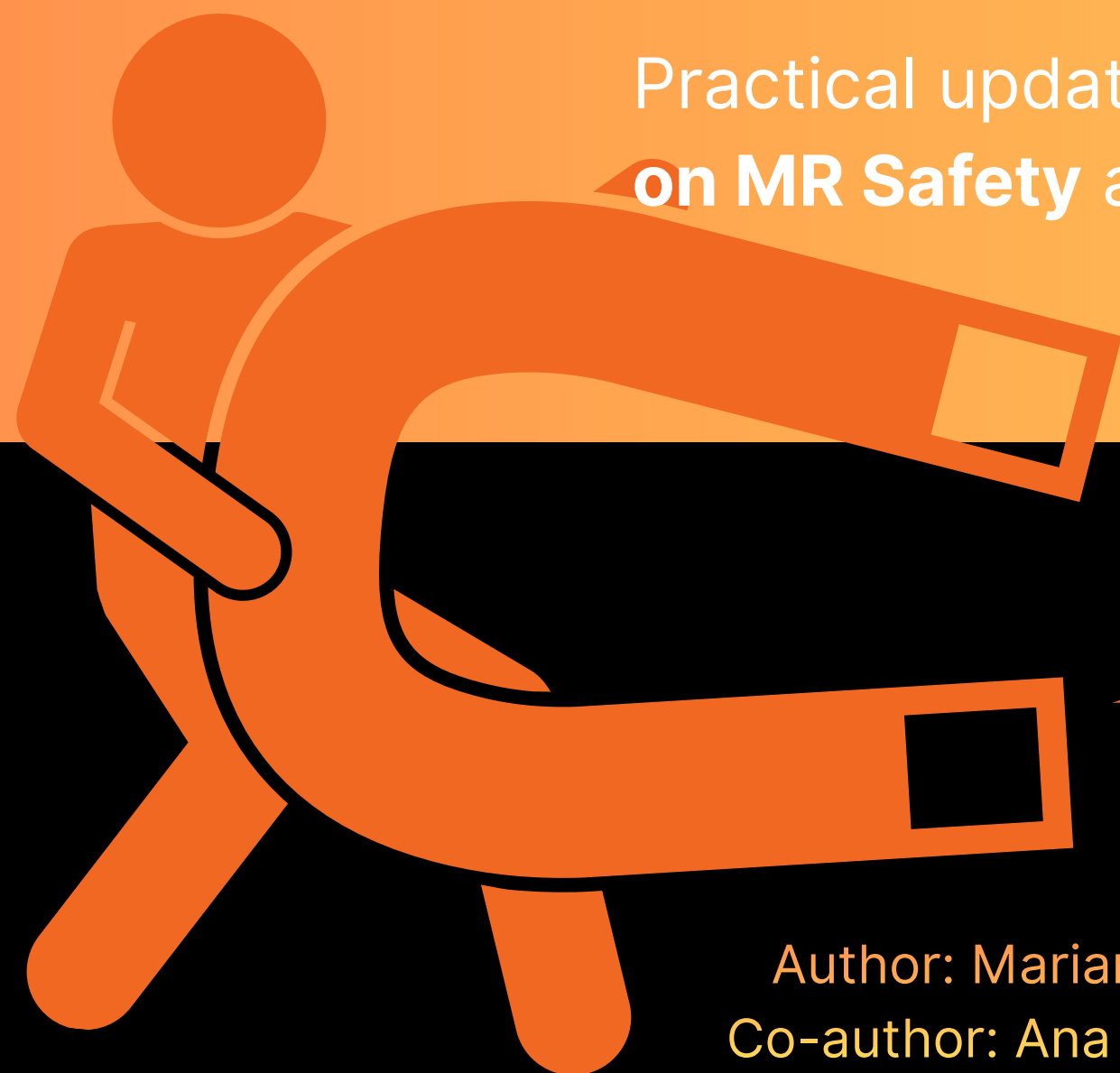




BEYOND THE MAGNET: MASTERING MRI SAFETY

Practical updates aligned with the **2024 ACR Manual on MR Safety** and current labeling (ASTM F2503).



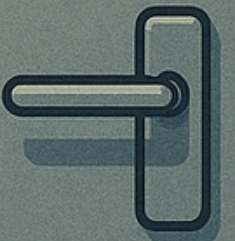
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Introduction

Why Safety Matters

Magnetic Resonance Imaging (MRI) is a powerful diagnostic tool, but it also presents unique safety challenges. Strong magnetic fields, rapidly changing gradients, and high-frequency radio waves require strict safety protocols to protect both patients and staff.

This presentation explores best practices, emerging technologies, and practical strategies to reduce MRI-related risks and improve patient outcomes, following the latest recommendations from the ACR Manual on MR Safety (2024).





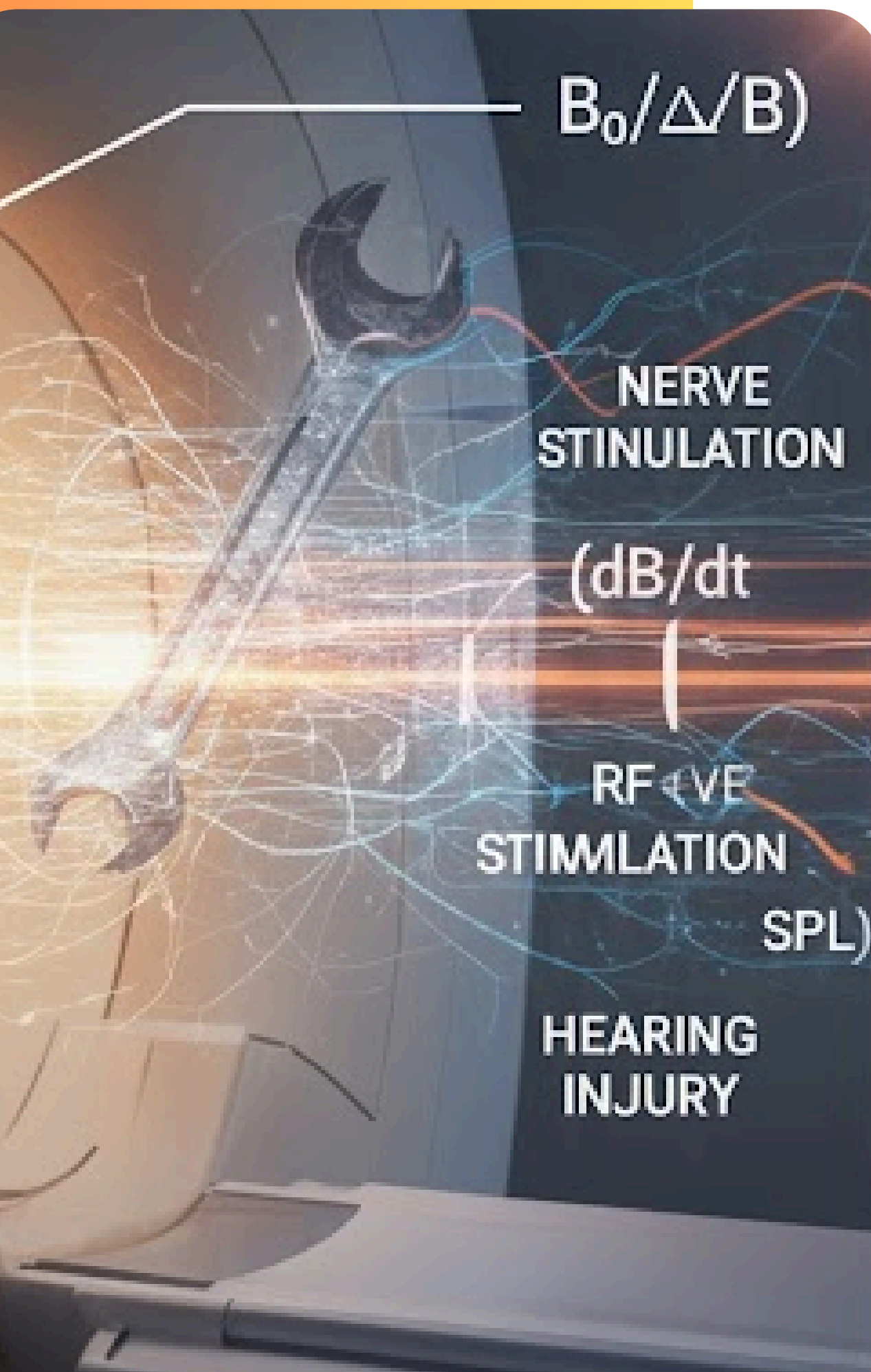
Scope

Whole-suite safety (patients, staff, visitors), covering risks from B0 (static magnetic field), dB/dt (time-varying gradient magnetic field), RF (radiofrequency; SAR = Specific Absorption Rate; B1+rms = root-mean-square RF field amplitude), GBCA (gadolinium-based contrast agents), and cryogenic events (helium quench/venting).



Outcome

Implementable checklists, device parameter sheets, and emergency action cards.



Objectives

> Recognize hazards:

Projectile effect, peripheral nerve stimulation (dB/dt), hearing injury (SPL), RF burns, quench hypoxia.

> Operationalize ACR zoning (I–IV)

with dual screening and a door re-check at III→IV, supported by ferromagnetic detection (FMD).

> Run MR-Conditional workflows

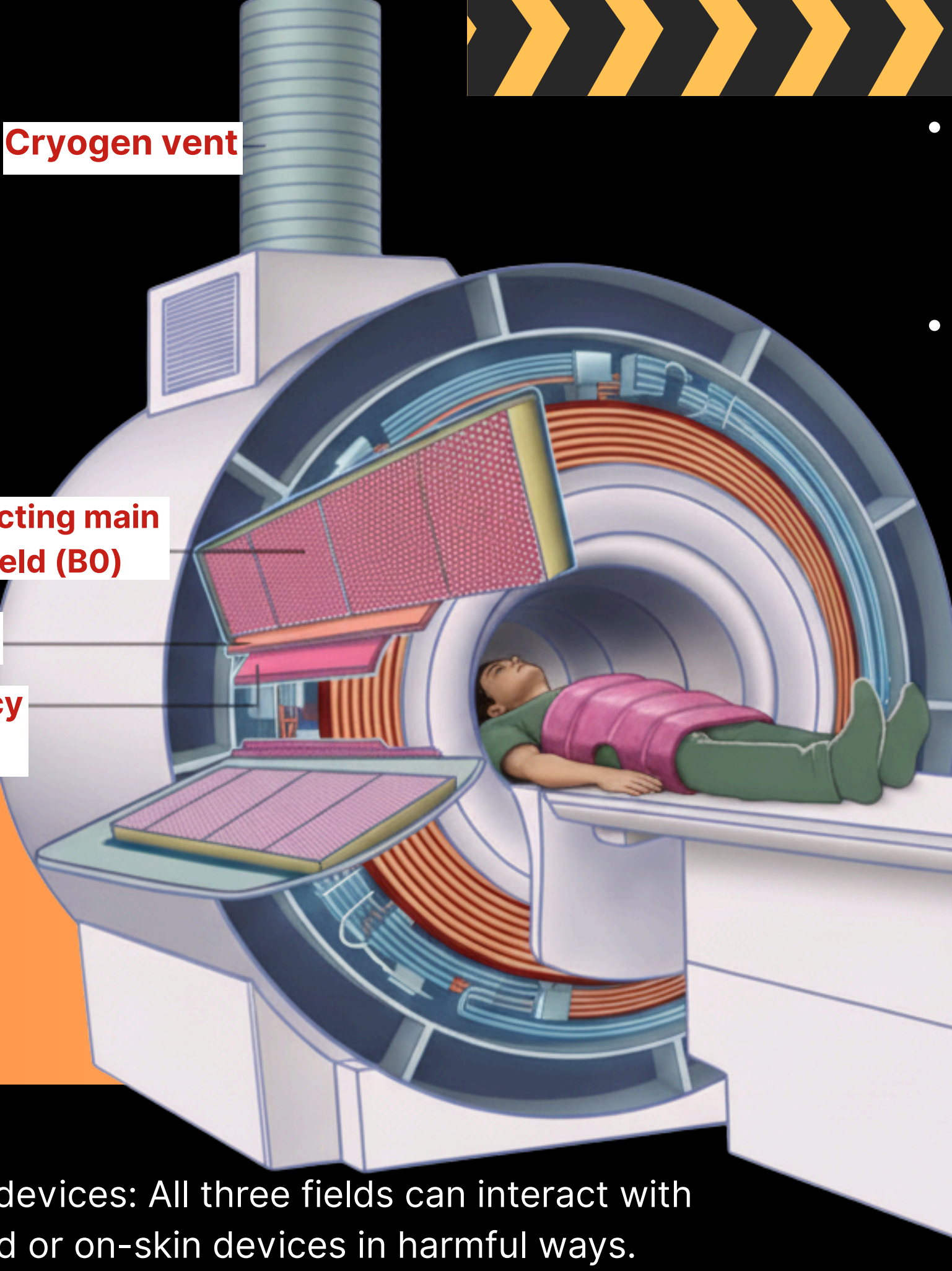
using the manufacturer's Instructions for Use (IFU): set limits for B_0 , spatial field gradient (SFG), B_1+rms/SAR , dB/dt , position/orientation.

> Standardize emergency response:

projectile, quench, fire, and code blue—prefer management outside Zone IV when feasible.

> Measure and improve:

near-miss/incident rates per 1,000 scans; checklist/door-check compliance; RCA and drills.



Cryogen vent

**Super conducting main
magnetic field (B0)**

Gradient coils

**Radiofrequency
(RF) coil**

- Serious harm has occurred in MRI. Most events stem from unsafe practices or failure to follow policies/procedures; true equipment failure is rare.
- **Three magnetic fields = three risk types:**
 - **B0 (main field):** ferromagnetic translation/torque → projectile incidents.
 - **B1 (time-varying RF magnetic field):** heating and burns.
 - **dB/dt (time-varying gradient magnetic field):** acoustic injury and peripheral nerve stimulation (PNS).

WORKPLACE SAFETY TRAINING

- Medical devices: All three fields can interact with implanted or on-skin devices in harmful ways.
- Additional risks (e.g., contrast, cryogenic events)

Small Misses, Big Consequences

01

High severity, low frequency:

Most catastrophic events involve unauthorized ferromagnetics (O₂ cylinders, tools) or RF-related burns from cable loops or skin-to-bore contact.

02

Primary drivers:

human factors (incomplete screening, rushed turnover), missing device info (no IFU), and process gaps (no door re-check).

03

System lens:

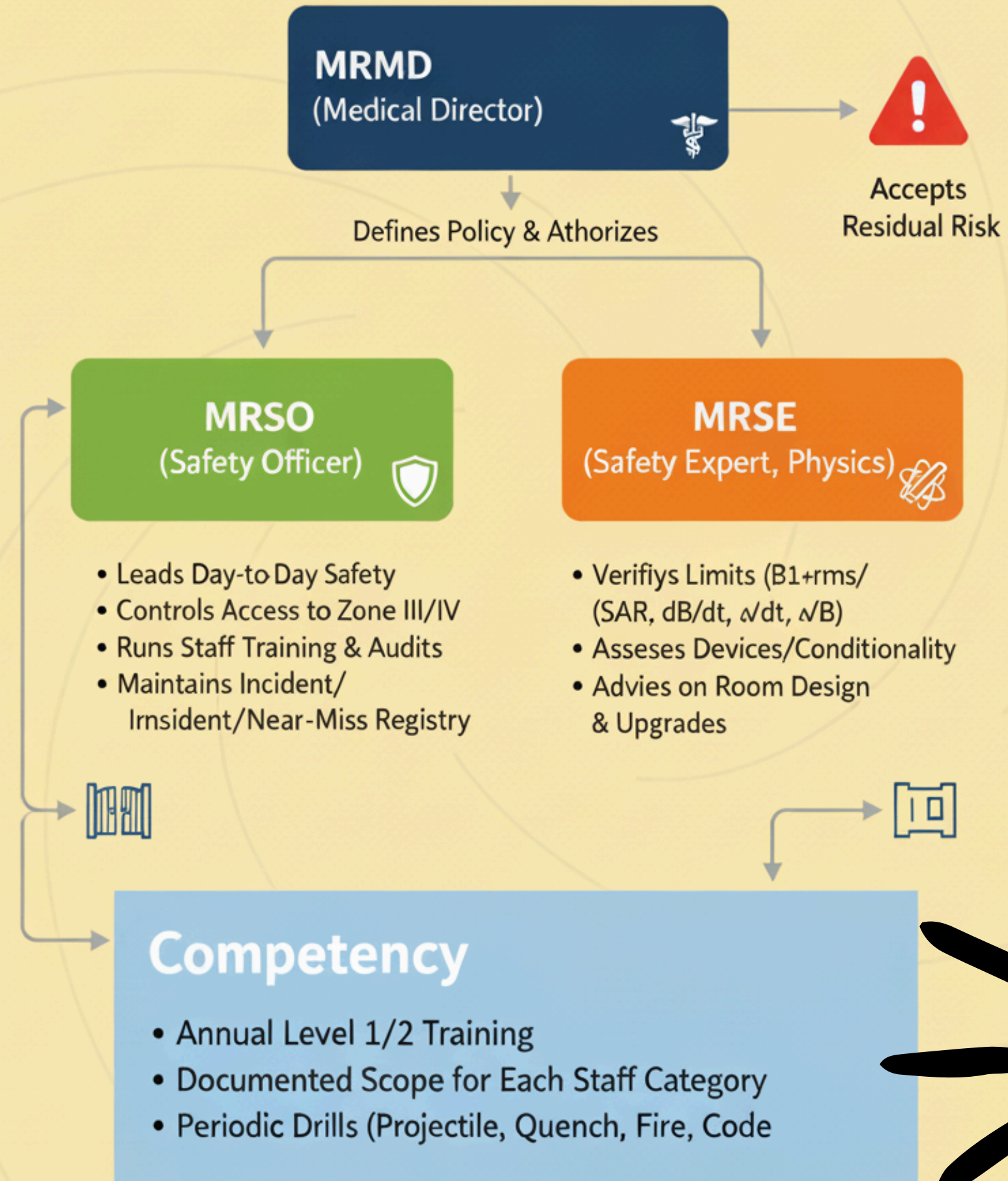
Safety emerges from People (roles & training) × Process (zoning & checklists) × Physics (limits & controls).

PEOPLE + PROCESS + PHYSICS

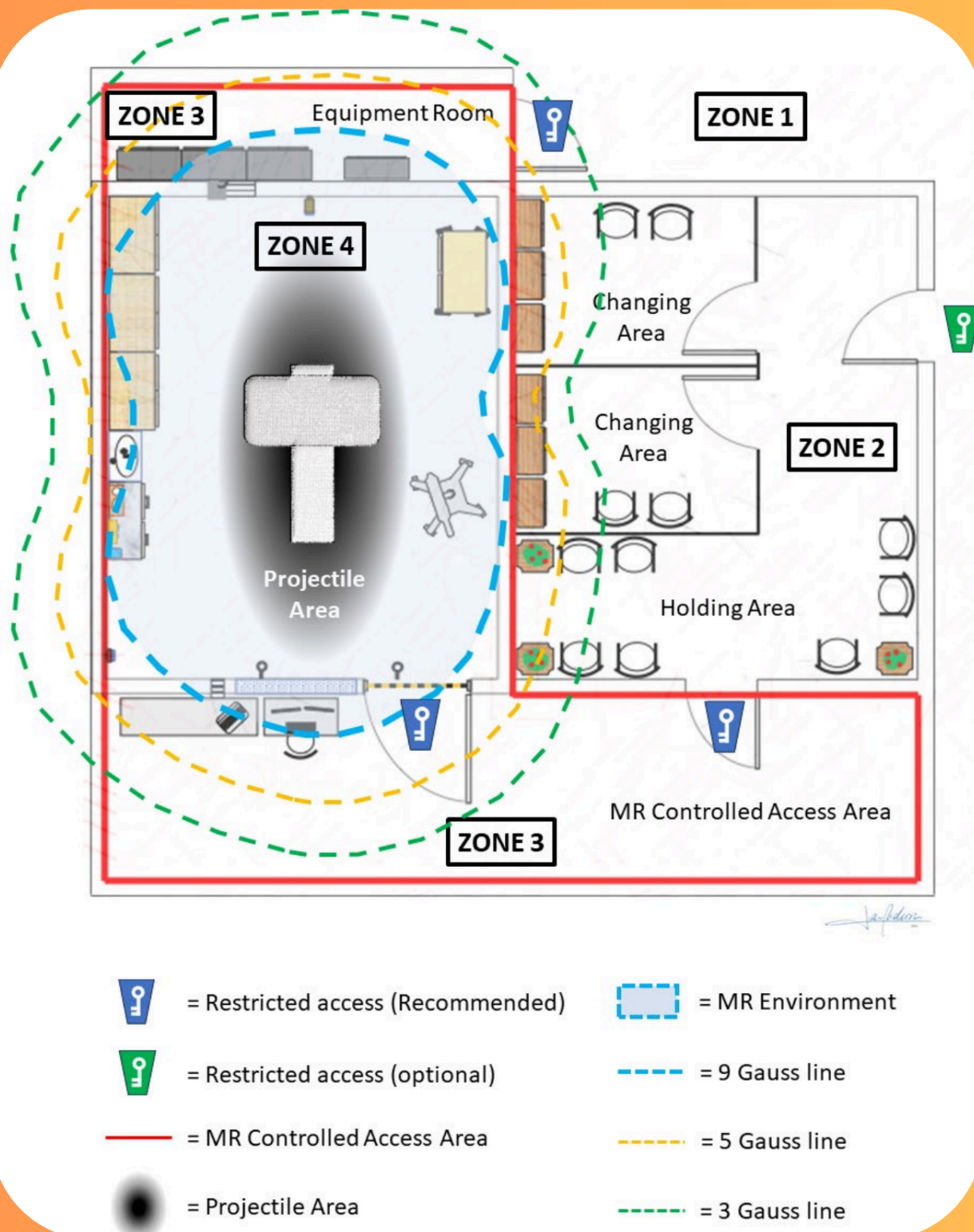
All three must align on every case



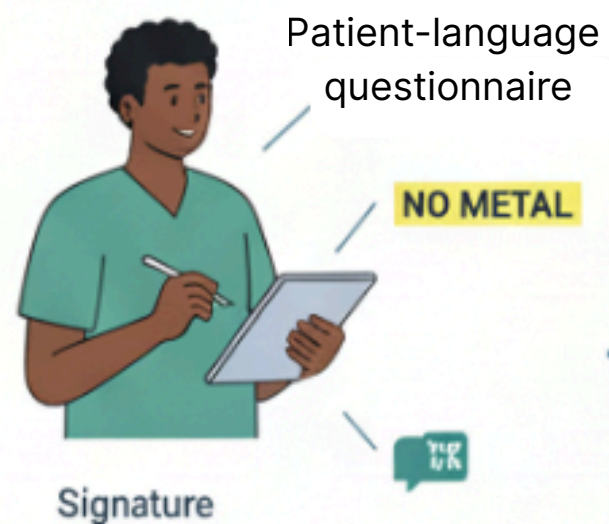
MRI Safety Roles & Governance



ACR Safety Zones



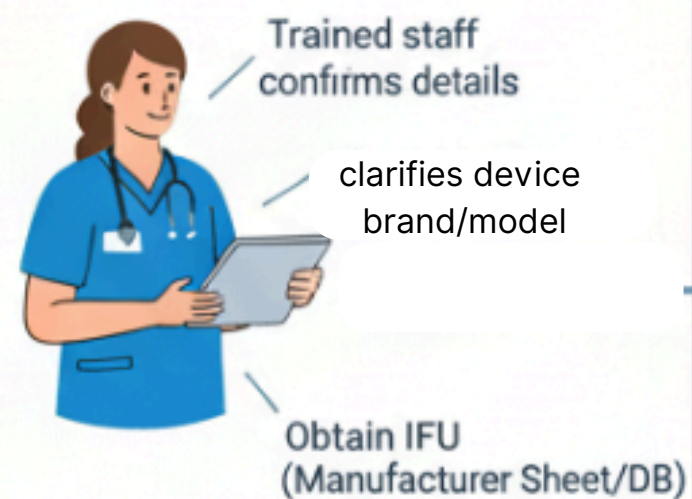
STEP 1 (PAPER/APP)



- highlight devices
- surgeries
- tattoos
- transdermal patches
- cosmetics with metal
- occupational exposures (welding).

MRI safety screening protocol

STEP 2 (INTERVIEW)

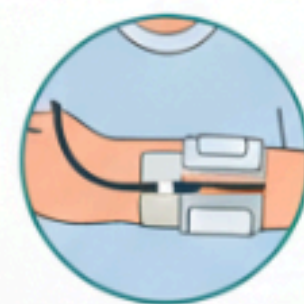


DOOR RE-CHECK (III→IV)



Hearing protection in place (plugs + muffs).

Patches: evaluate adhesive, backing, heating risk; remove/replace if not MR-safe per vendor guidance



Cable routing verified:
no loops;
not touching skin;
padding placed.



ASTM F2503 Labeling (How to Use It)



Practice: For every Conditional device, load the IFU (PDF or database), extract the exact limits, record them in a Parameter Sheet, and configure the console accordingly

MR SAFE

No known hazards in any MR environment.

MR CONDITIONAL

Safe only if specific conditions are met (e.g., B0, SFG, B1+rms/SAR, dB/dt, position).

MR UNSAFE

Do not enter MR environment..

EXTERNAL DEVICES & ZONE DISCIPLINE

- **Label before Zone III:** Portable metallic equipment must be labeled (MR Safe/Conditional/Unsafe).
- **If MR-Unsafe must be in Zone III: Secure/tether** and manage responsibly.
- **Reduce projectile risk:** Use **pocketless scrubs** for anyone entering Zone IV.



IMPLANTS: ACTIVE, PASSIVE & IN-SCAN DISCOVERIES

- **Active devices (CIEDs, neurostim, pumps):** Follow **device-specific MR conditions exactly**.
 - **CIEDs without MR-Conditional labeling** may be scanned **only** under a program consistent with **Heart Rhythm Society** recommendations.
- **Passive metal implants:** Cannot be **MR Safe**—only **MR Conditional** or **MR Unsafe**.
 - A prior uneventful MRI **does not prove safety** for future exams.
- **If an unknown implant appears during the exam:**
 - **Extensive susceptibility artifact** can suggest unsafe ferromagnetic content.
 - Follow SOPs to **remove the patient from the magnet**: slow table speed and keep the patient **recumbent** until well away from the bore.



Static Field (B_0) & Spatial Gradient (SFG)

What this means

- B_0 = the magnet is **always on**. It pulls **ferromagnetic** objects (steel, iron).
- **SFG** = where the pull gets stronger. Near the bore, the pull changes fast → higher risk.

Big risks

- **Missile (projectile)**: loose ferromagnetic items can fly toward the magnet.
- **Implant movement**: some implants can **twist or shift** in the magnetic field.

How to prevent it

- **At the door (Zone III → IV)**: do a strict check + **FMD** scan.
- **Keep metal out**: anything ferromagnetic that isn't essential stays out of Zone III.
- **Use MR-compatible gear**: stretchers, oxygen, monitors must be **MR-safe/conditional**.
- **Know your hot spots**: mark or memorize where **SFG is highest** around your scanner.



Gradients (dB/dt) – PNS & Acoustic Noise



What it is

- The scanner's gradient coils turn on/off very fast. That changing field can affect nerves and make loud sounds.

Big risks

- **PNS (nerve tingling/twitching):** more likely with very fast sequences (e.g., EPI) and large body scans.
- **Loud noise:** peak sound levels can go **>99 dB**.

How to prevent it

- **Hearing:** give **both** earplugs **and** earmuffs to **everyone** in Zone IV.
- **Sequences:** if the patient feels tingling, slow the sequence, reduce gradient strength, or switch protocol.

Devices & leads

- Changing fields can interact with **conductive leads/cables**.
- **Follow the device IFU** and **note the operating mode** (normal vs first-level controlled) on the worksheet.

Time-Varying RF Magnetic Field (B1)



Most common event: RF burns.

Before the scan

- Remove all **removable conductors**; use pocketless **MR-safe gowns** (don't trust clothing labels).

Positioning

- **Insulate and separate** skin from the bore and any **cables/metal**.
- Avoid **conductive loops** (including the patient's own tissue) and **skin-to-skin contact** → pad small contact areas.
- If the **body coil transmits**, route **leads/wires** along the **centerline**, away from bore walls.

Objects/implants

- **Metallic clothing, tattoos, close dermal implants, and drug patches** (may contain metal) ↑ heating risk.
- **MR-Conditional** at one **field strength** ≠ safe at others; **follow the IFU exactly**.
- **Detachable T/R coils** can reduce heating in selected cases.

Dose & modes

- **SAR** controls tissue heating; **Normal Mode** lowers whole-body risk but **doesn't eliminate burns**.
- **First-Level Controlled** may **increase risk** → requires **medical supervision**.
- **SED/SA** = total absorbed energy; **shorter sequences + cool-off periods** reduce risk.

GBCA (Gadolinium) – Essentials



Safety first:

- With **macrocyclic agents**, the risk of **NSF** is **very low**.
- If **eGFR < 30**, think twice: consider **no contrast** or alternatives if the scan still answers the question.



Pregnancy & lactation

- **Pregnancy:** delay non-urgent scans; use only if benefits clearly **outweigh risks**.
- **Breastfeeding:** no routine interruption needed.



Good practice

- **Document** brand, lot, and dose.
- **Watch** for reactions during/after the scan.
- Be **ready to treat anaphylaxis** (drugs, equipment, trained staff)



Special Populations & Active Devices

— Simple Guide —

> Pediatrics / Neonates

- Keep the child **warm** and use **MR-compatible monitoring**.
- **Double hearing protection** (earplugs + earmuffs) is **mandatory**.
- **Screen the caregiver/parent** if they go inside.

> Active implants (MR-Conditional: pacemakers, neurostimulators, etc.)

- Get the **exact model** and the **manufacturer IFU**.
- If required, **program the device to MRI mode** before the scan.
- Follow the IFU limits and setup: **patient position, B1+rms/SAR, gradient limits (dB/dt)**.
- **Document** the settings you used.



Special Populations & Active Devices — Simple Guide—

> Sedation / Anesthesia

- Use **MR-safe airway/ventilation** equipment.
- When possible, manage the airway **outside Zone IV**; plan the route in and out.

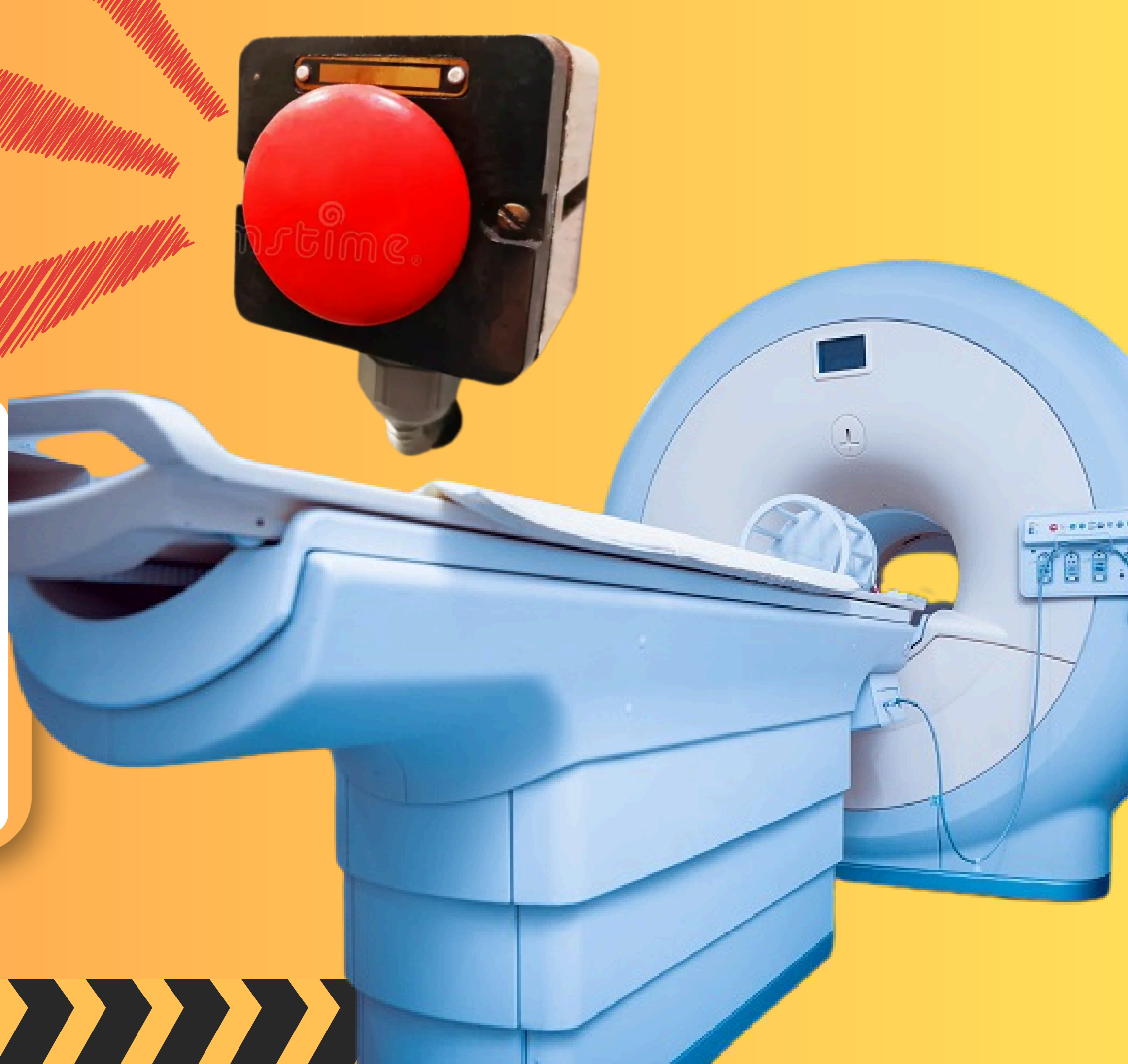
> Critical care (ECMO, pumps, etc.)

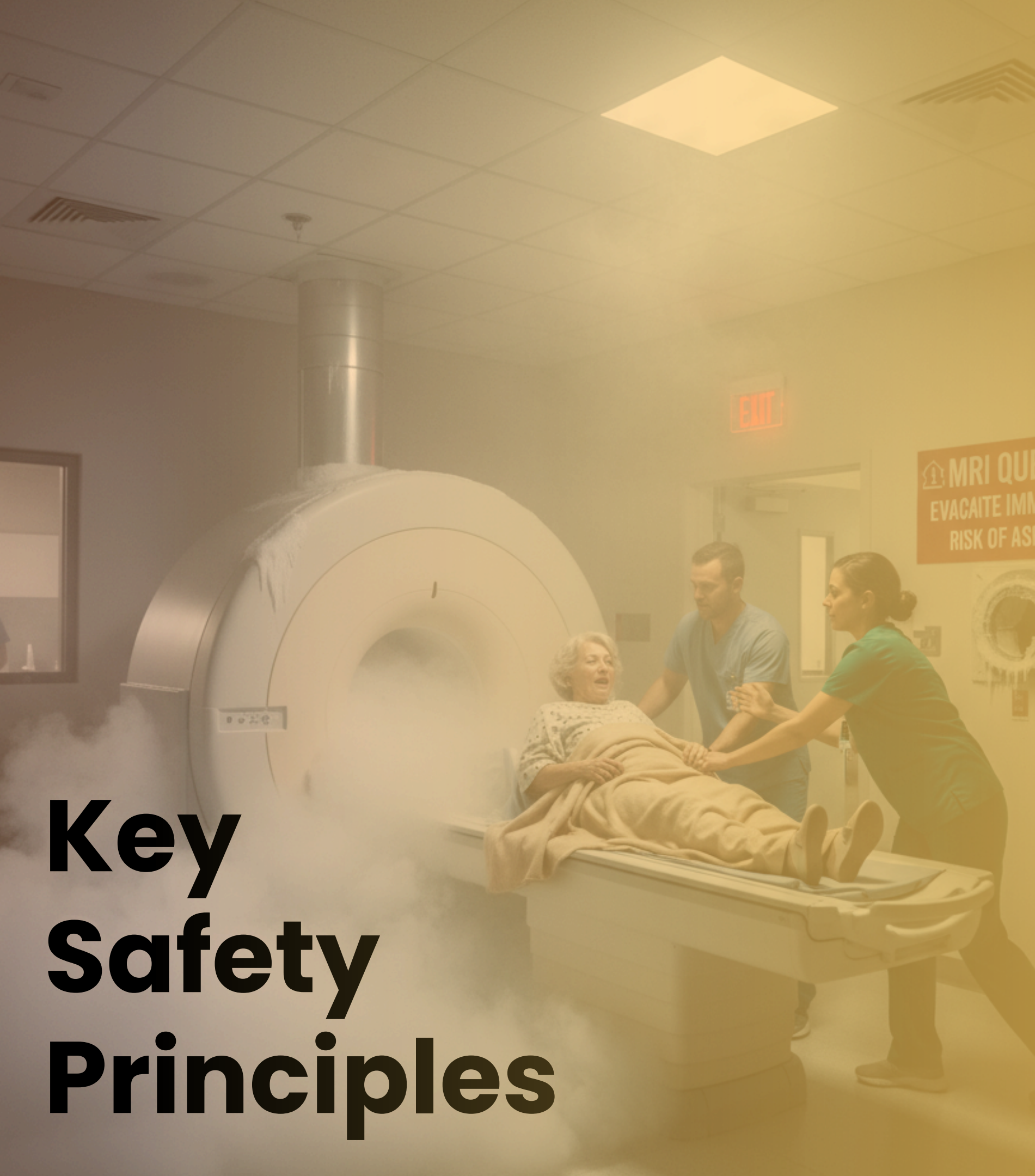
- Use **pre-approved MRI pathways** for these patients.
- Bring **only MR-compatible equipment** into the room; park the rest outside.
- Have a **backup plan** if alarms or lines need attention mid-scan.



Emergency Procedures – Overview (ACR 2024)

- ACR 2024 emphasizes that every MRI service must have **written policies and procedures** and **clearly defined roles (MRMD/MRSO/MRSE)** for emergencies in the MRI environment.
- At a minimum, plans must cover: **projectile events, quench** (emergency demagnetization), **fire**, and **code** (cardio-/respiratory arrest).
- The manual outlines **responsibilities** and stresses **regular training and drills**.



A photograph of an MRI room during a quench event. A patient is lying on the MRI table, which is partially inside the large, white, cylindrical magnet. Two medical staff members, a man and a woman, are standing next to the table, looking at the patient. The room is filled with a thick, white fog or steam, obscuring the background. A red "EXIT" sign is visible on the wall. A sign on the wall reads "MRI QUI EVACATE IMM RISK OF AS".

Key Safety Principles

Quench & Evacuation

Goal: Protect patient and staff during helium venting and loss of magnet field.

Key actions (ACR 2024):

- **Recognize** quench signs (noise/fog, sudden field loss) and the risks of **hypoxia** and **cold** in the room.
- **Evacuate** patient and team to **Zone III**, **secure/close** the Zone IV entrance, and **notify** engineering/physics.
- **Verify** room oxygen levels and **vent stack integrity; document** the event (planned vs. accidental) and **corrective actions**.
- Maintain **written procedures** and **defined roles** for these tasks; conduct **regular drills**.



Projectile event (Zone IV):

Stop the scan; **do not pull** the object against the magnetic field.

Stabilize the patient, **restrict access**, and **coordinate safe extraction** with physics/engineering per the site plan. Report the incident and perform a root-cause analysis to prevent recurrence.

Projectile

- Use a non-ferromagnetic extinguisher; move the patient to Zone III if it is safe to do so.
- Follow the local protocol and document the incident.

Fire

(cardio/respiratory arrest)

- Prefer resuscitation outside Zone IV; if not possible, use MR-compatible equipment only.
- Keep egress routes clear and preassign roles for rapid transfer.

Code



Operational Flow — Simple & Friendly —

- Scheduling & Pre-screen
- Device verification (brand/model/IFU)
- Consent/education
- Clothing/lockers
- Door check (FMD + verbal
+ hearing protection + cables/padding)
- In-scan monitoring & comms
- Exit + adverse symptom query
- Incident/near-miss log



TIP



Laminate and post this flow near Zone III.

Between patients

- **Wipe** coils and table with approved cleaner.
- **Replace** pads and linens every time.
- **Separate** inpatient textiles from outpatient ones.

Isolation cases

- Follow the **right pathway** for **contact / droplet / airborne**.
- **Coordinate** with Infection Prevention (IP) for room entry/exit steps.
- Use **MR-compatible** PPE and accessories only.

Room turnover

- Use a **standard short checklist** (the “minimum clean”) matched to the exam type.
- **Initial & log** each turnover.

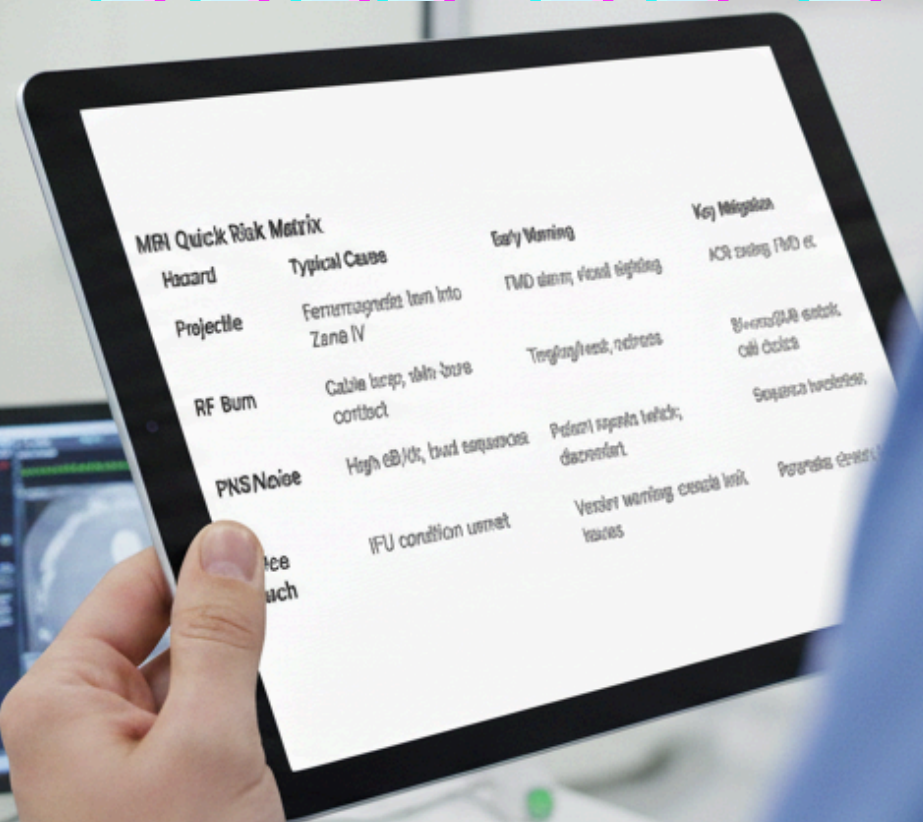
Infection Prevention in MRI — Quick Workflow—



MRI Quick Risk Matrix

Hazard	Typical Cause	Early Warning	Key Mitigation
Projectile	Ferromagnetic item into Zone IV	FMD alarm; visual sighting	ACR zoning; FMD at door; dual door check
RF Burn	Cable loop; skin-bore contact	Tingling/heat; redness	B1+rms/SAR control; cable elevation; padding; coil choice
PNS/Noise	High dB/dt; loud sequences	Patient reports twitch; discomfort	Sequence tweaks; double hearing protection
Device	IFU condition unmet	Vendor warning; console limit	Parameter sheet; MRMD/MRSD/MRSE sign-off

QUICK RISK MATRIX



METRICS & CONTINUOUS IMPROVEMENT (WHAT TO TRACK)

- **Incidents & near-misses** per **1,000** scans; classify by hazard type (projectile, RF, gradient, GBCA, cryo).
- **Checklist compliance** (pre-scan + door re-check) via periodic spot audits.
- **Room-turn time** (safety-neutral) to detect rushed steps.
- **Monthly RCA** review; update policy and **quarterly drills** accordingly.

Essential Training for a Hazard-Free Environment



Future Directions



- **Smarter screening with AI:** Software scans the **electronic medical record** for any implants or devices, pulls the maker's **Instructions for Use**, and suggests the safe scanner settings for that patient.
- **Live safety on the console:** The scanner shows simple, real-time warnings about **how strong the transmit radio wave is**, **how much energy the body is absorbing**, and **how fast the gradients are switching**—so staff can lower risk before harm happens.
- **Smart MRI rooms:** The room's safety systems work together—**ferromagnetic detectors** lock or alert, the system tracks who enters, and the console pops up an automatic **door-check reminder** before anyone goes into the magnet room.

HANDOUTS (QR CODES SUGGESTED)

MR Safety Resources (ACR 2024)



Operational Checklist (EN, PDF)



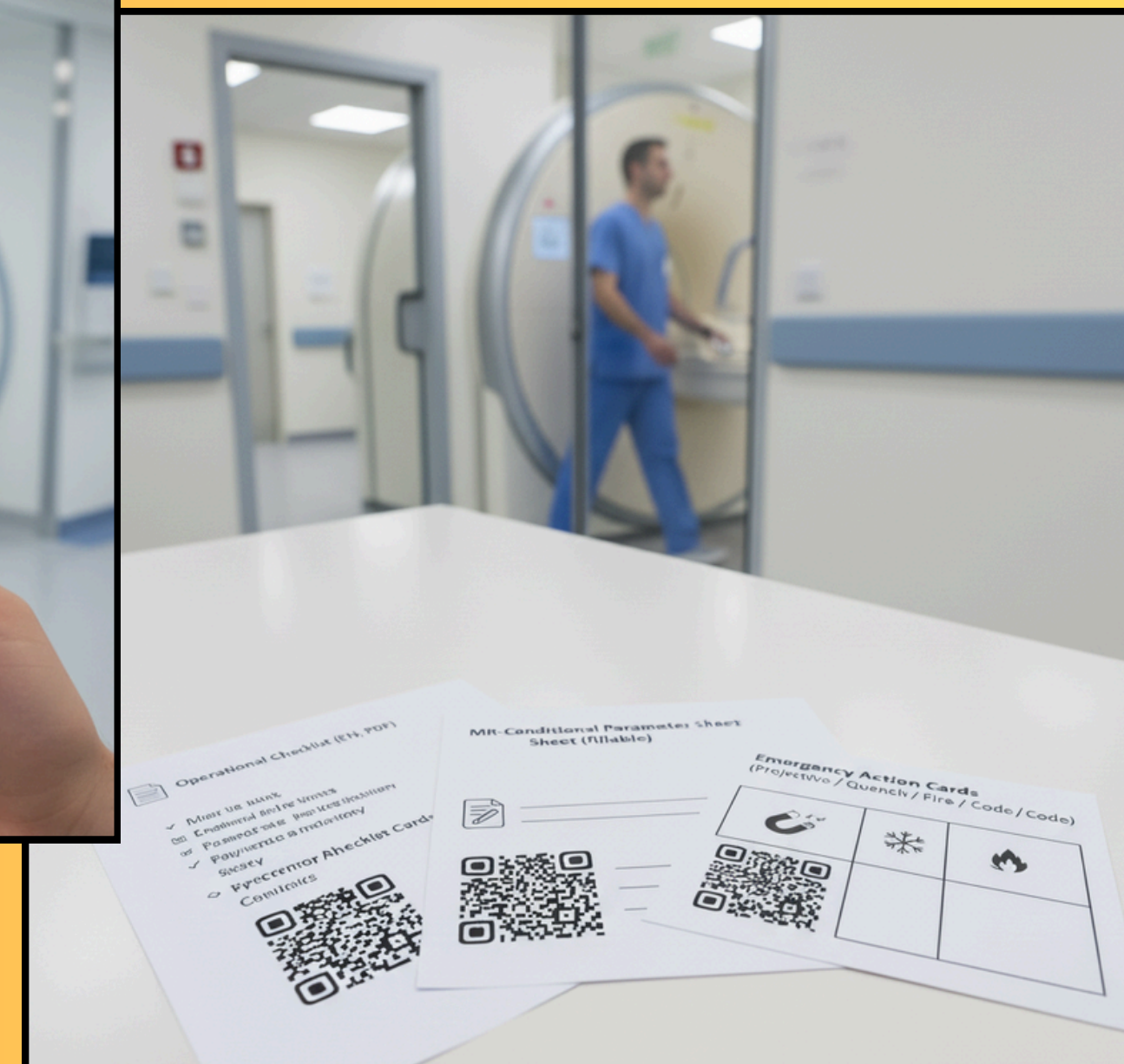
MR-Conditional Parameter Sheet (fillable)



Emergency Action Cards (Projectile / Quench / Fire / Code)



- **Operational Checklist (EN, PDF).**
- **MR-Conditional Parameter Sheet (fillable).**
- **Emergency Action Cards (Projectile / Quench / Fire / Code).**



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