



MRI SAFETY IN PEDIATRIC HOSPITALS: PITFALLS AND SPECIAL CONSIDERATIONS

Emily Gonzalez, MD, Jordan Han, MS, Charles Finch, MD, and Cory M. Pfeifer, MD, MPH

The authors have no disclosures.



Pediatric MRI Safety: Special Considerations for the Pediatric Population

1. Many children, especially young children, require general anesthesia to achieve diagnostic imaging quality.
2. Usage and safety regarding cochlear implants.
3. MR unsafe and conditional devices and alternatives
4. Children are often accompanied by caregivers who are frequently granted access to zone 4 during scanning.
 - Everyone entering zone 4 should have a screening form on file.
 - Different facilities have different protocols in place for the storage of these forms. In the case of patients, privacy regulations may not allow for these forms to coexist in the child's chart.



Michael Colombini: MR Safety Tragedy

July 26, 2001 a 6-year old boy died after undergoing a routine MRI exam, due to nearby oxygen tank hurled into the room by the magnet.

Small Town Reels From Boy's M.R.I. Death

By DAVID W. CHEN AUG. 1, 2001

Michael died on Sunday. The tragedy has touched off visceral waves of emotion in this close-knit village of 7,600 people. Everywhere in Croton, it seemed, people had Michael on their minds: parents who were reminded they could not guarantee their children's safety, youngsters who clung tighter to their mothers and fathers, people who wondered whether the child's death was an unavoidable accident or a dreadful medical error.

Radiologist's Deposition

5 Q Do you recall -- when you say you used to give
6 IVs for people receiving MRs when there is a
7 contrast media involved, during that period
8 were you ever given any training in MR safety,
9 you know, vis-a-vis the MR environment?
10 A I would suspect that I was, but I don't
11 specifically recall a MR education safety
12 training that I received.
13 Q Do you recall ever being educated with respect
14 to different types of oxygen canisters in a MR
15 environment?
16 A No.

The radiologist responsible for the safety of the MR environment did not recall any safety training.



American Board of Magnetic Resonance Safety

Since this time the American Board of Magnetic Resonance Safety was created with the goals of defining the knowledge base required for those charged with ensuring safety in the MR environment and creating tests to ensure that this knowledge base was sufficiently present, and to credential those professionals in positions of responsibility and authority over MR site safety.

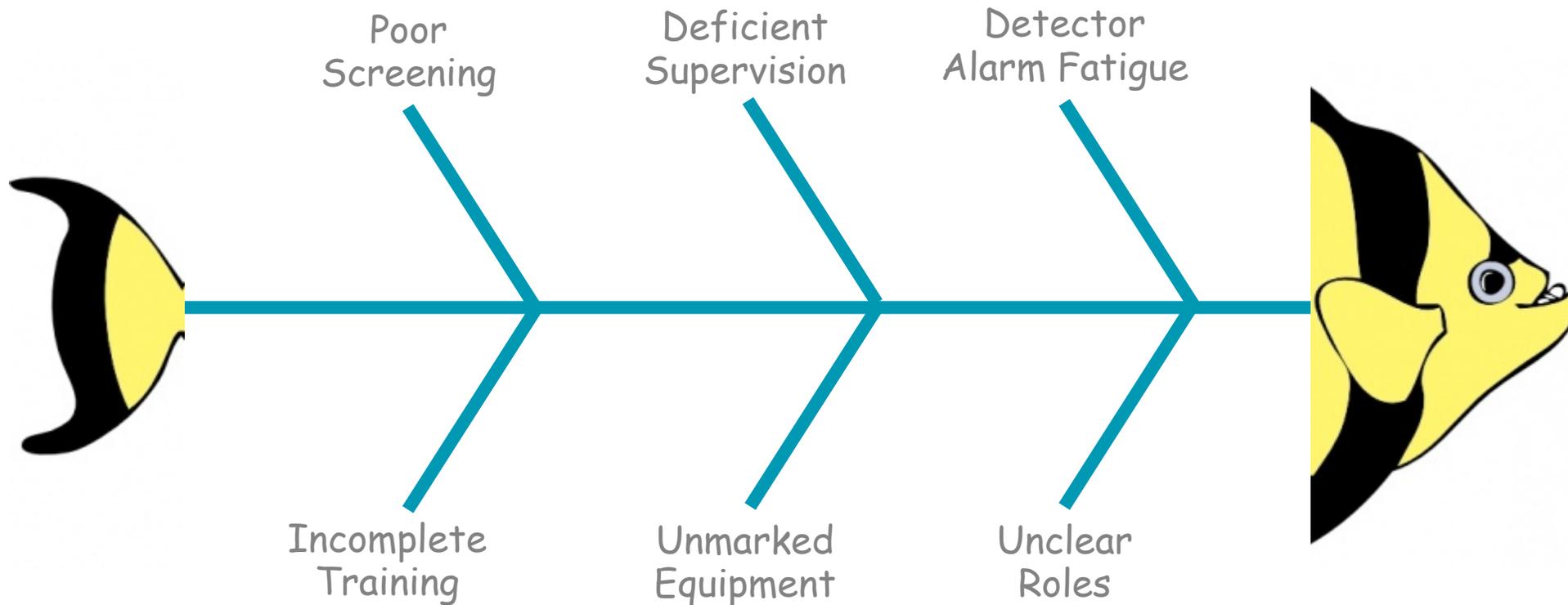
Credentials available for physicians, MR safety officers (typically MRI technologists), and MR safety experts (often medical physicists). MRMD/MRSO/MRSE respectively.

We endorse the ABR supplanting the ABMRS MRMD (MRSC™) credential with a separate ABR board certification.

Source: American Board of Medical Resonance Safety. <https://abmrs.org/about-abmrs/history/>



When things go wrong... Root Cause Analysis (RCA)



Root Cause Analysis (RCA) is a process in which hospital quality committees review an incident to determine what happened and how to prevent future events. A fishbone (Ishikawa) diagram shown here is an example of how this process can be depicted.



Static Field—Typically 1.5 or 3.0 Tesla (**ALWAYS ON!**)

Translational pull is greatest close to the center of the bore but not in the center. Center of the bore is the isocenter; Spatial magnetic gradient is greatest just around the isocenter

Example: undisclosed ferrous aneurysm clip.

Safest place for clip is either outside of Zone IV or in the isocenter of the magnet

Patient must be slowly and carefully removed if an unexpected aneurysm clip is found

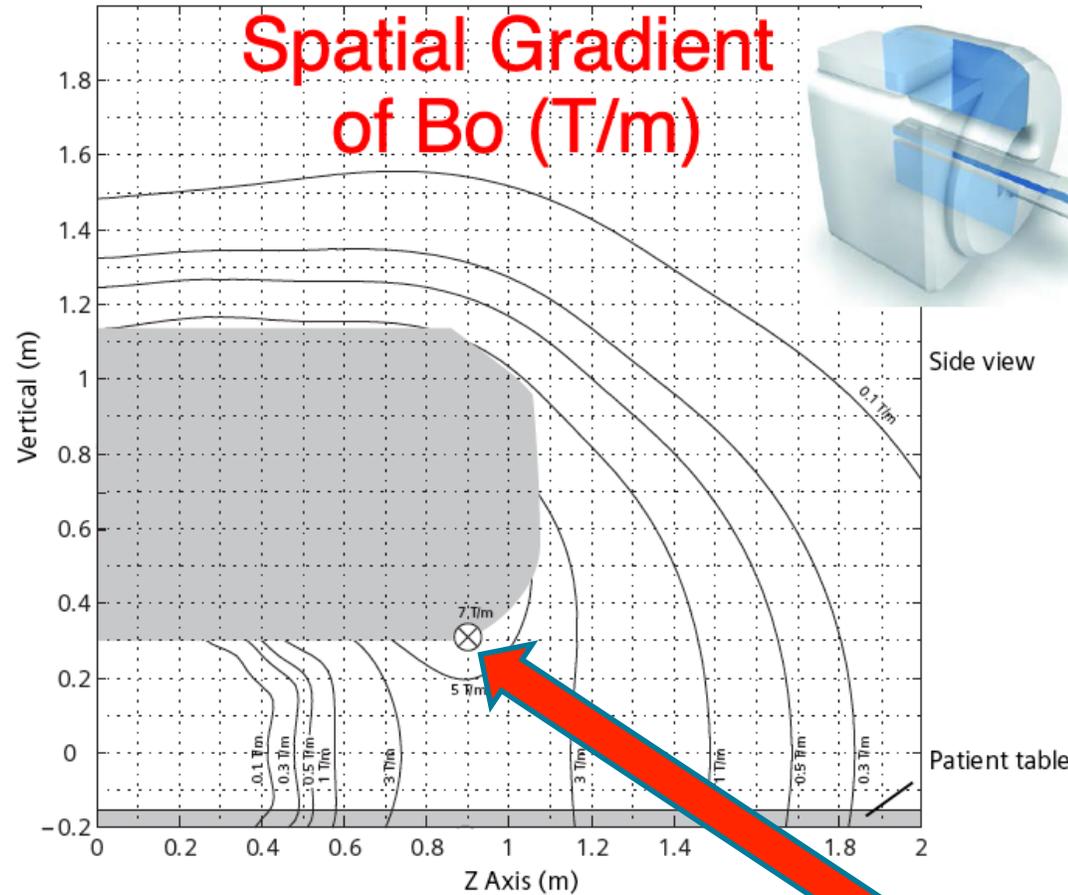
All equipment in the MR environment should be tagged MR Safe, MR Conditional, or MR Unsafe

Increased artifacts for some implants and increased safety risk for some implants

Common for an implant to be conditional at 3T and unsafe at 1.5T—important with growth in use of 3T in pediatric imaging



Spatial Gradient of the Static Field



Maps are often provided in Tesla/m

$$1 \text{ T/m} = 100 \text{ G/cm}$$

Commonly tested demarcation of 720 G/cm is often chosen because it is often higher than the patient will experience during the exam

A device may be conditional at 720 G/cm when tested (deflects less than 45 degrees) at 1.5T, but the same cannot be inferred at 3T.

~700 gauss/cm



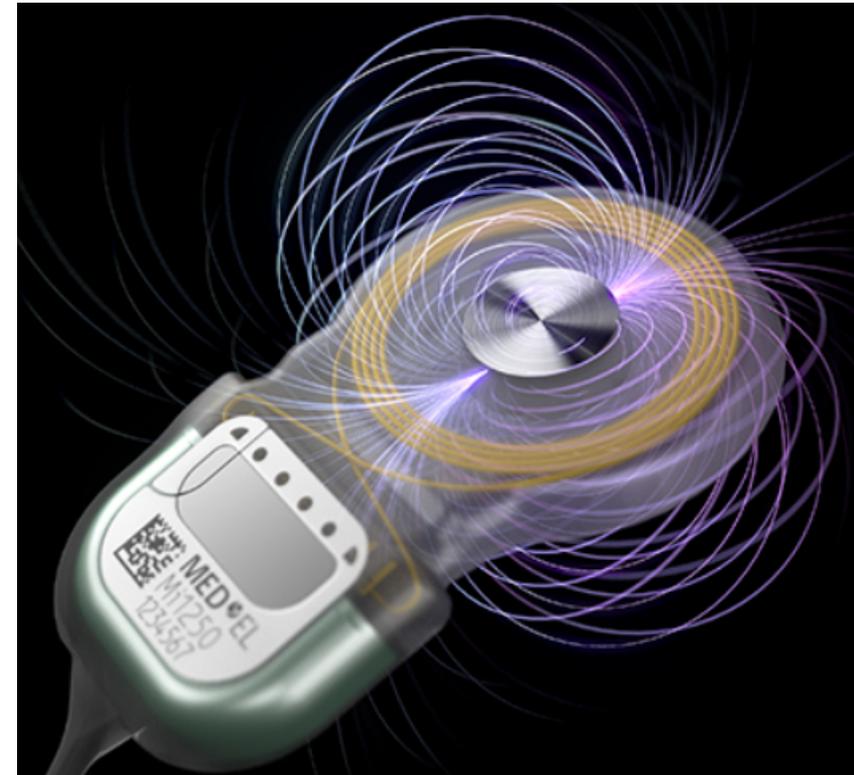
Cochlear Implant Safety

External sound processor is typically **MR unsafe** and must be removed before patient enters zone 4.

Internal components contain magnets, some of which are removable.

Med-El models have a diametric rotatable MR conditional magnet.

Splinting: splinting is required for some devices, and at least one manufacturer stopped selling their kit in the United States.* Many institutions have opted to continue splinting with a bandage.

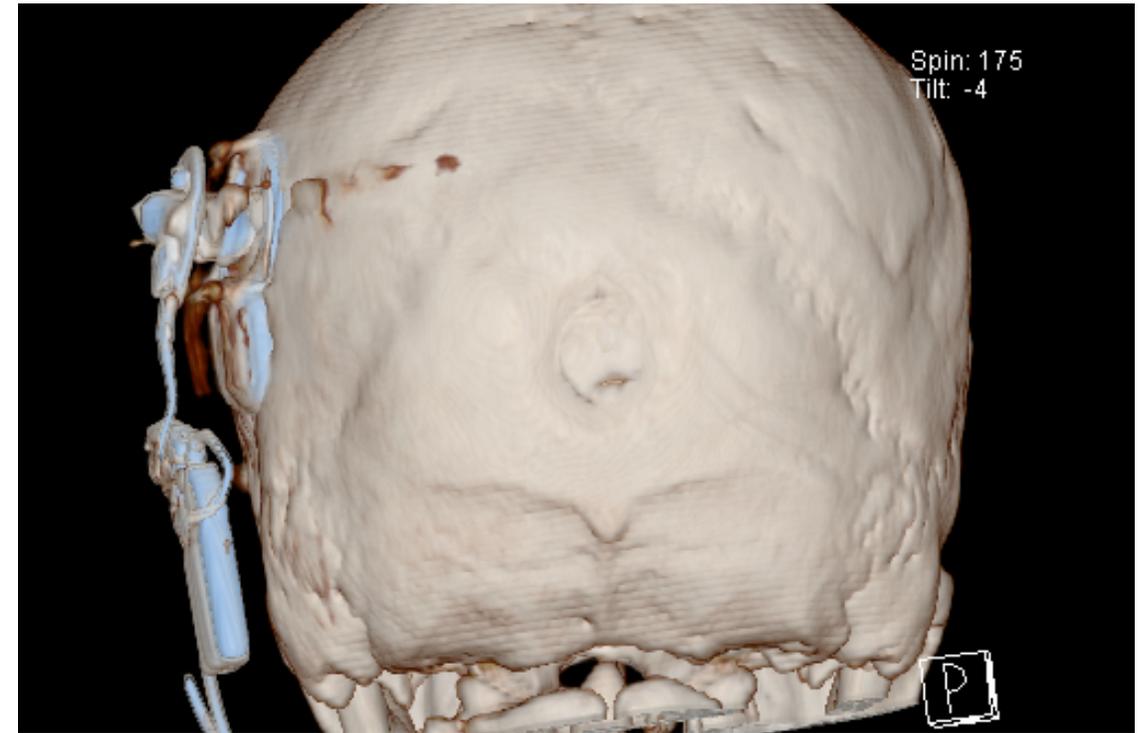
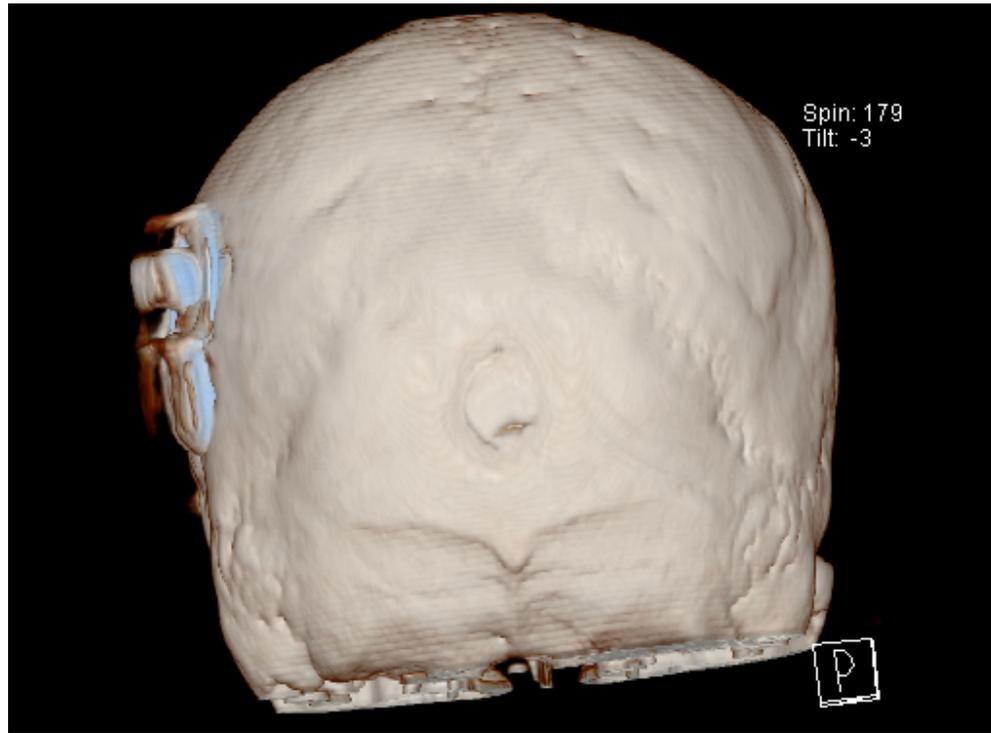


Source: Med-El Blog. <https://blog.medel.pro/introducing-revolutionary-new-s-vector-magnet-technology/>

*Source: Cochlear Nucleus Implants MRI Guidelines. <https://mss-p-007-delivery.sitecorecontenthub.cloud/api/public/content/35b777b60ec947ba9a99971b4d700f5b?v=d9d865c0&MOD=AJPERES&CVID=mZJ0AKH>



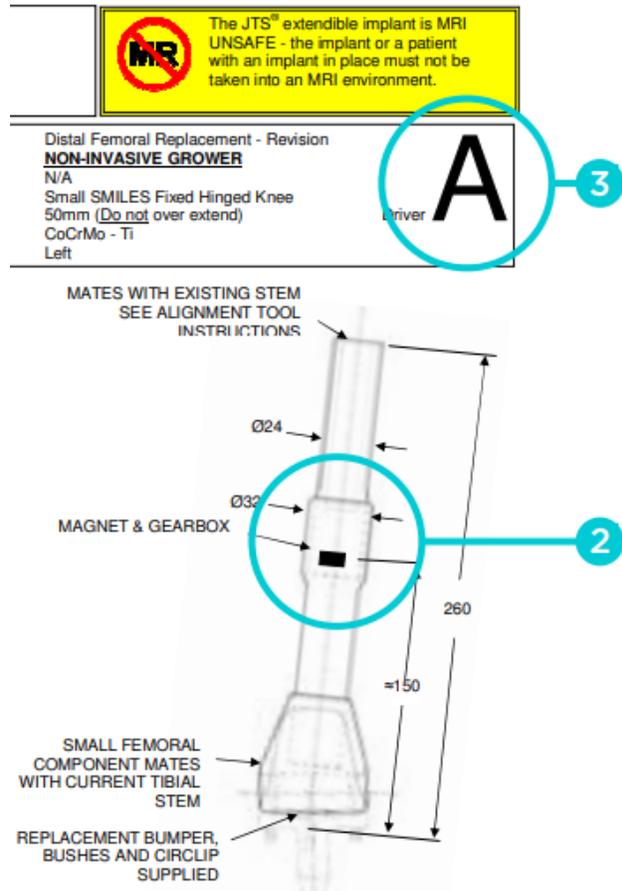
Cochlear Implant Migration



3D reconstructions of two head CTs show migration of a cochlear implant. Prior to MRI, the cochlear implant is appropriately positioned (left). After MRI, the implant has migrated due to misunderstanding of the manufacturer's safety information (right).



Magnet-Containing Prostheses



“Grower” device

If used in a cancer patient, this device is **MR unsafe** if follow-up imaging is needed (e.g. cancer diagnosis)

Source: JTS Quick Start Guide. https://www.hpra.ie/docs/default-source/field-safety-notice/july-2017/v32423_fsn.pdf?sfvrsn=2



Stimulators

Device may have specific MRI conditions depending on body site.

Device may have been tested in very specific scenarios.

The implantable pulse generator and lead may have different conditions.

Providers likely to order repeated MRI benefit from consultation with MRI safety personnel to consider an optimal combination for all parties.

Table 3. RF field requirements (see Table 4 for additional scanning requirements)

IPG Model	Lead Model	Scan Region	RF Coil	RF Power (SAR)	Notes and Warnings
Proclaim Elite 3660 3662	Penta 3228	Any body part	Body RF transmit coil with any receive-only coil (quadrature only)	Whole body SAR ≤ 0.1 W/kg	<p>WARNING: Personnel knowledgeable in MR safety should be involved to optimally plan the scan and actively monitor SAR levels during the scan. Ensure the scanner displays SAR prospectively. Exceeding these SAR limits could increase the risk of excessive heating of implanted components.</p> <p>NOTE: To allow the MRI scanner to estimate the SAR, ensure that you enter the patient's body weight accurately into the scanner.</p> <p>WARNING: Before an MRI scan, determine the patient's body temperature. If the patient has a fever, you should not perform an MRI scan.</p>
		Head scans	RF transmit-receive head coil (quadrature only)	Normal operating mode	<p>WARNING: To avoid excessive heating that could cause serious patient injury, do not place any part of the RF transmit-receive coil over any implanted neurostimulation system component.</p> <p>WARNING: Only quadrature, birdcage RF transmit-receive coil designs have been tested. Do not use other transmit coils designs (e.g., linear, phased-array, or saddle) because these have not been tested and could result in serious patient injury.</p> <p>WARNING: Scans of the hips and shoulders are excluded and have not been tested using RF transmit-receive coils.</p> <p>WARNING: Before an MRI scan, determine the patient's body temperature. If the patient has a fever, you should not perform an MRI scan.</p> <p>WARNING: Do not conduct MRI scans in first-level controlled or second-level controlled operating mode. These modes allow higher levels of RF energy and may cause excessive heating of implanted components, which could result in serious patient injury.</p> <p>NOTE: The SAR requirements will be met if the scanner is in normal operating mode.</p>
		Extremity scans	RF transmit-receive extremity coil (quadrature only)	Normal operating mode	<p>WARNING: Scans of the hips and shoulders are excluded and have not been tested using RF transmit-receive coils.</p> <p>WARNING: Before an MRI scan, determine the patient's body temperature. If the patient has a fever, you should not perform an MRI scan.</p> <p>WARNING: Do not conduct MRI scans in first-level controlled or second-level controlled operating mode. These modes allow higher levels of RF energy and may cause excessive heating of implanted components, which could result in serious patient injury.</p> <p>NOTE: The SAR requirements will be met if the scanner is in normal operating mode.</p>

Example of MR conditions.



Heating Concerns During Scanning

Magnetic fields in a looped device can create current.

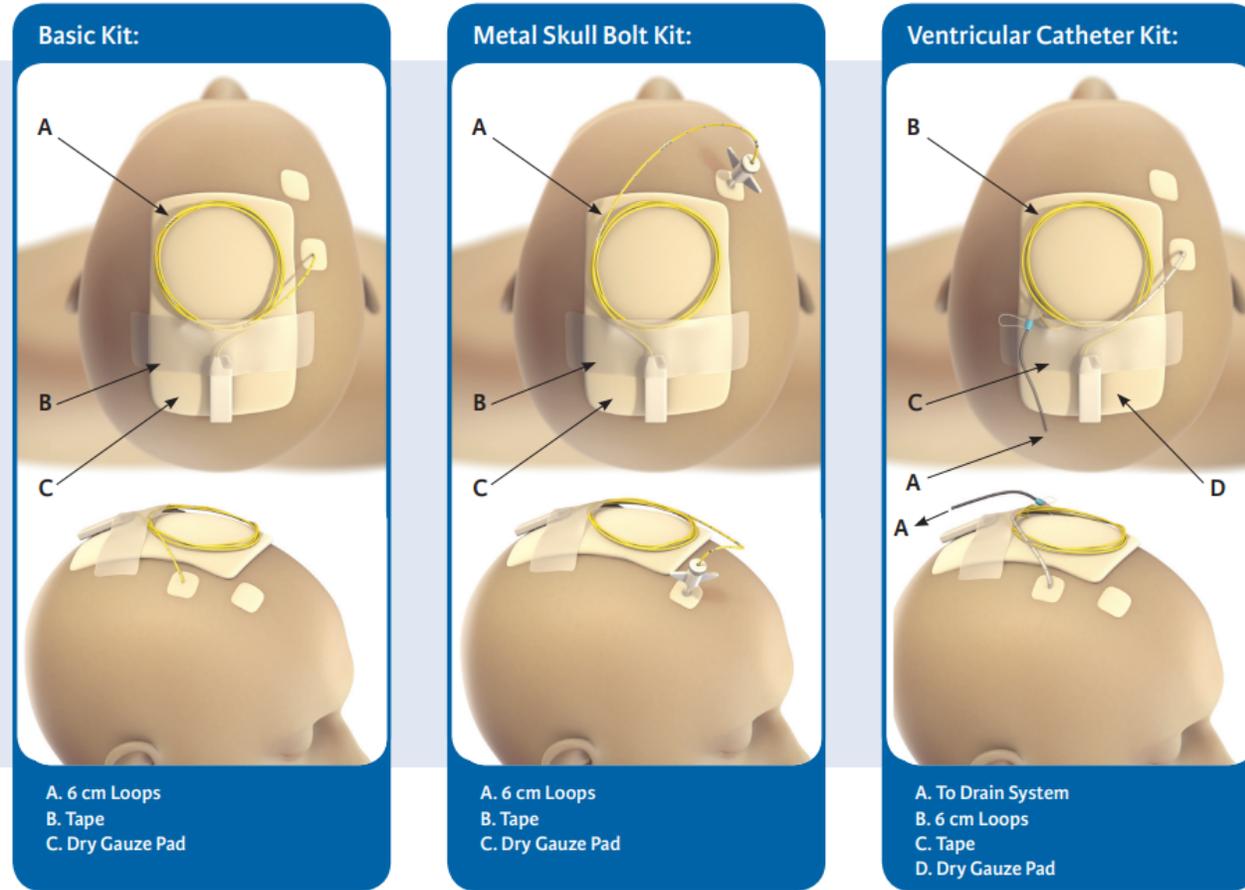
Additional metallic products such as tattoos, silver-containing antimicrobials, nail polish glitter, and hair products may cause heating.

Have a policy in place to address these elements.

Technologists are compelled to follow the policy in place, per Joint Commission requirements.



Required Configuration: Codman Microsensor®



Source: CODMAN MICROSENSOR® ICP Transducer MR Technician Notice. <https://www.integralife.com/file/general/1571417954.pdf>



Gadolinium

Routine eGFR calculation is optional with Group II agents (MultiHance[®], Gadavist[®], Dotarem[®], and ProHance[®])

In pediatrics, some institutions may consider the neonatal period to infer a de facto state of temporary renal insufficiency

Good protocols should limit gadolinium-based contrast agents to necessary indications and at the lowest dose.

Source: ACR Manual on Contrast Media, 2021.

https://www.acr.org/-/media/ACR/files/clinical-resources/contrast_media.pdf



Thank You!

