MAGNETIC RESONANCE IMAGING

Surgical Specialty:	Non-OR Anesthesia (NORA)
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Background:

- General Considerations
  - Magnetic resonance imaging (MRI) is performed in children for a variety of indications that require in-depth imaging of various parts of the body.
  - The strong magnetic field in the MRI scanner necessitates that no ferrous objects be in close proximity, as these can become hazardous projectiles. Special care must be taken to ensure that MRI-compatible anesthesia equipment is used. Induction and emergence from general anesthesia typically take place in a room outside the scanner.
  - General anesthesia is frequently required in children due to the requirement to be immobile for the length of the imaging, which can range from 45 minutes to several hours.
  - Because of the large degree of variation in the physical layout and types of MRI procedures required amongst institutions, there is no standard way to provide anesthesia for an MRI.
  - Anesthesia for MRI does not require analgesics as there is no pain associated with the scan.
  - Children should be assessed in advance by the radiology staff or child life teams to see if the scans can be performed awake with parental presence or distraction technologies such as MRI-compatible headphones for music or movies.
    - MRI-safe distraction technology varies significantly by institution.
- Patient Considerations
  - It may be preferable to secure the airway for anesthetized neonates and infants undergoing MRI because the time it takes to access and rescue the airway of a small child deep in the scanner may be too long, given the quick desaturation time in this age group.
  - Children with obesity, severe scoliosis, or contractures may not fit in standard MRI coils and may require special positioning and consultation with a radiologist for optimal imaging.
  - MRI may be contraindicated in children with some implanted devices, such as pacemakers or some surgical clips, and some devices such as ventriculoperitoneal (VP) shunts, may require reprogramming after the scan.
- Associated Comorbidities/Syndromes
  - Older children with autism or other behavioral diagnoses may require anesthesia more frequently than children without these diagnoses because they may be less

likely to tolerate an MRI awake. If uncooperative, due to their size and strength, these children often require additional preoperative preparation, including premedication via the oral, intranasal, or intramuscular route.

Anesthetic Planning:

- Pre-Anesthetic Evaluation
    - An MRI-safe screening form must be completed in advance by the radiology team to identify any implants or devices that are not MRI-compatible.
    - Implants and medical devices should be labeled as MR Unsafe, MR Conditional, or MR Safe. Patients with MR Unsafe devices should not be scanned. Patients with MR Safe devices have no scanning restrictions. Patients with MR conditional devices may only safely enter the scanner room if the specific conditions for the safe use of their device are met.
    - Ensure any ferromagnetic medication patches, insulin pumps, or continuous glucose monitors are removed and that a plan is in place for post-operative reprogramming of VP shunts if necessary.
    - Patients with obstructive sleep apnea may be at higher risk of requiring advanced airway placement due to obstructive breathing patterns under anesthesia.
        - Patients may require an advanced airway for their safety or because head or chest movement during snoring may cause too much motion artifact for quality MRI images.
- Specific or Unique Room Set-Up Requirements
    - The MRI environment is divided into four Zones designated I- IV.
        - Zone I has no detectable magnetic field. This area is accessible to the public outside the MRI area, and usually includes the reception and waiting areas.
        - Zone II is the area between Zone I and Zone III. It also has no detectable magnetic field, but access is often restricted because it is close to the MRI scanner.
        - Zone III is restricted to MRI personnel and/or patients, and includes the control room and induction room.
        - Zone IV is inside the room containing the MRI scanner.[1]
    - Check if a separate anesthesia induction room is available outside the scanner.
        - If anesthesia induction must occur in the scanning room (Zone IV), ensure MRI-compatible emergency airway equipment is available.
    - In many institutions, the anesthesiologist may sit in a control room adjacent to the scanning room for the duration of the scan as long as the patient can be seen and the vital signs can be monitored from the control room.
    - MRI-safe monitor, infusion pump, and anesthesia machine must be used inside the scanning room (Zone IV).
    - Extended length tubing for intravenous (IV) lines and oxygen tubing is often required, as well as circuit extenders to lengthen the anesthesia machine breathing circuit, especially if the patient is head first in the scanner.

Intraoperative Considerations:

- General
    - Vascular access requirement is typically a single 22 or 24 gauge peripheral IV.
        - If contrast is required, it can often be administered through the same IV as that is used for the anesthetic, but check with the radiology tech if there is a size

requirement for the IV, especially if the contrast will be bolused via a pump versus hand injected.

- Induction
  - Standard pediatric mask or IV induction occurs preferably in a separate induction room (Zone III) outside the MRI scanning room (Zone IV).
- Airway
  - While spontaneous ventilation with a natural airway and nasal canula is often possible, an advanced airway may be necessary due to patient or exam specific factors.
    - Some specialized MRI sequences may require breath holds, which is an additional indication for advanced airway placement.
  - If an advanced airway is required, the pilot balloon must be secured into position with tape to avoid motion artifacts due to the presence of a small amount of ferromagnetic material in the pilot balloon.
- Positioning
  - Hearing protection should be applied to the child.
  - Abdominal or chest imaging may require arms in the pull up position.
    - Ensure that the shoulders are positioned at less than 90 degrees to reduce stretch on the brachial plexus.
  - Depending on the scan, the child may be head first in the magnet, increasing the difficulty and time to access their airway in case of an emergency.
    - Consider the child's predicted time to desaturation if spontaneously ventilation with a natural airway.
    - Possible indication for an advanced airway in infants.
- Maintenance
  - Once an IV is established, an infusion of propofol, with or without dexmedetomidine or other IV adjuncts provides excellent anesthesia.[2]
  - High dose dexmedetomidine as a single agent is also successfully used at some institutions. While often associated with a decrease in heart rate and blood pressure, studies suggest these are typically within 20% of baseline values and not associated with adverse sequelae.[3]
  - Anesthesia gases such as sevoflurane can also be used via a facemask or advanced airway.
- Hemodynamic/Physiologic Goals
  - MRI-safe monitors can suffer from frequent interference depending on the MRI sequence, adding additional challenges to hemodynamic monitoring.
  - Very little hemodynamic change is expected during the anesthetic due to the lack of pain associated with the scan and minimal anesthetic required.
  - Due to a lack of stimulation, hypotension is not uncommon, especially with a pure propofol anesthetic. This may be treated with fluids or vasoactive agents, although it can be challenging, given the lack of access to the patient and IV lines.
  - Temperature
    - Temperature should be monitored, if possible via an MRI-safe probe.
    - The scanning room must be kept cool for optimal MRI machine operation.
    - Temperature regulation can be challenging, especially in small children.
    - Active warming devices are not MRI-compatible.
    - The cooling fan in the magnet can be turned off to decrease heat loss, and the patient should be covered in warm blankets.
- Emergence/Disposition

    - After the conclusion of the MRI scan, children should be transported back to the induction room for emergence, and then recovered in PACU or PICU as appropriate.
- Post-op Care
    - Children tend to emerge quickly, given the minimal amount of anesthetic required for scans.
    - Children with programmable VP shunts will need the shunt reprogrammed prior to PACU discharge.

Case Specific Complications/Pitfalls

- Common complications
    - Airway obstruction
        - Requiring airway manipulation or advanced airway
    - IV contrast reaction
    - Hypothermia
    - Positioning injury
        - Due to prolonged immobility or pull up arm position
    - Burn injury
        - Due to ferromagnetic objects inadvertently retained near the patient
- MRI enterography
    - An emerging technique that involves the administration of enteric contrast material, and is highly effective at assessing for inflammatory bowel disease.
    - In awake patients, oral and IV contrast is administered, but administering oral contrast within two hours of anesthesia is at odds with the American Society of Anesthesiologists nil per os (NPO) guidelines due to safety concerns with the risks of anesthetizing a child with a full stomach for an elective MRI.
    - Various institutions have developed their own approaches, with some allowing oral contrast via an NG or NJ tube placed after a child is anesthetized and intubated, with stomach suctioning at the conclusion of the scan prior to extubation.[4]
    - One institution has developed radiology protocols that instead allow for rectal administration of contrast in anesthetized patients that is advanced into the small bowel.[5]
        - Caution is advised with airway protection even under these circumstances, as the increased intraabdominal pressure from filling the bowel with contrast material can lead to shallow breathing and atelectasis or aspiration of residual gastric contents.
- Functional MRI
    - Protocols vary by institution but can include the requirement of either passive or active patient participation- a unique challenge in patients who require anesthesia.
    - Propofol infusion can be used for the majority of the case, but discussion should take place with the radiologist if there are specific parts of the scan where sedation should be lightened or briefly ceased.
    - A background infusion of dexmedetomidine can be continued while propofol is either decreased or stopped during the functional assessment part of the scan.

References

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