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Practice Guidelines for the MRI & MRT

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Introduction

Magnetic resonance imaging (MRI) is used increasingly to improve accurate diagnosis and define plans for therapy. The technique of MR imaging makes considerable demands on patients who are required to remain more or less immobile in a confined space for 30-60 minutes. The long cylindrical configuration of the MRI tunnel may be frightening to a young child and provides limited access and visualization of the patient by the anesthesiologist asked to sedate the patient for the scan. Monitoring equipment has to be specifically made to be MRI compatible and the equipment may malfunction in proximity to the magnet because of the high magnetic field strength. In addition, ferrous objects brought into the scanning room may become dangerous missiles, potentially injuring the patient or MRI technicians, or damaging the scanner. In the last several years, the applications of the MRI have expanded from a purely diagnostic modality to a tool for the guidance of minimally invasive diagnostic and interventional procedures. There are several reasons for this development. First, the MRI allows pathological lesions to be delineated with a high level of sensitivity. Second, the multiplanar images allow for a better understanding of anatomical relationships. Third, the real-time monitoring allows for immediate evaluation of any surgical intervention. Lastly, another important property of MRI is lack of ionizing radiation, which is an advantage for the patient and for the person performing the procedure.

Monitors and Equipment

1. The electrocardiogram introduces problems with both image degradation from wire leads acting as antennas and the inability of the ECG monitor to discern the ECG from the background static magnetic field and radiofrequency pulses. Voltage induced in the wire leads may pose burn and electrical shock hazards to the patient. It is important to keep limb leads close together and in the same plane, parallel to the magnetic field. Leads V_5 and V_6 maximized QRS and minimized artifact. It is also important to make sure that all leads are insulated from the skin of the patient. There are currently several electrocardiograph devices reported acceptable for use in the MRI. At present we are not currently using any of these in our MRI scanner, although our MRT scanner will eventually be equipped with one.
2. Pulse oximetry is essential and is currently used on all anesthesiologist-administered sedation and general anesthetics. These monitors, however, are susceptible to interference from the changing magnetic field and will occasionally be briefly deactivated by radio frequency pulses. It is very important to use a nonferrous pulse oximeter and to place the probe on a distal extremity as far from the scan site as possible. When an ECG is not available, it is useful to follow the pulse rhythm and rate with the oximeter.
3. Blood pressure monitoring during MRI can be accomplished using the oscillometric method (Dinamap). Invasive blood pressure monitoring can also be obtained in the MRI. A high pressure, low compliance extension tubing connected to an arterial catheter, with the transducer placed at the level of the right atrium, beyond the 50 Gauss line can be used without the magnetic field altering transducer performance.
4. Capnography has been successfully used. However, because of the long gas pathway the waveform shows a prolonged upslope. Although the end-tidal CO_2 concentrations are not accurate, it is useful to monitor respiratory rate, to follow trends, and to detect if a circuit disconnection has occurred.
5. Temperature monitoring can be accomplished in the MRI with temperature probes that use radiofrequency filters or with nonferromagnetic skin temperature strips that use a liquid crystal display. Care must be taken to avoid hypothermia in all patients, especially in the pediatric population. Airflow directed through the scanner can cool an infant rapidly. Warmed bags of intravenous fluids, single-use thermal packs, airway humidification, and covering the patient are ways to avoid excessive heat loss.

Anesthesia Machine

There are several MRI compatible anesthesia machines available on the market. The machine currently in use at Stanford is made by Ohmeda and uses a ventilator that is pneumatically driven by an aluminum oxygen cylinder. The North American Drager anesthesia machine has an MRI electronic ventilator. This machine will soon be available at Stanford.

Problems in the MRI

1. **Patient Accessibility**- the patient's distance from the anesthetist creates problems with airway management, intravenous access, patient visualization, and monitor application. If unintentional extubation occurs, it is necessary to discontinue the scan and bring the patient out to the foot of the scanner bed. Reintubation must take place outside the magnet room because laryngoscope batteries are ferromagnetic
2. **Burns in the MRI**- risks from burns can be minimized by following some simple precautions:

    - check that the insulation on all monitoring wires and cables are intact
    - do not form loops within the magnetic bore
    - minimize contact between cables
    - remove any wires or leads not in use
    - separate cables from skin
    - keep the cable and sensor away from the examination area e.g. place a pulse oximeter on the toe of a patient whose head is being examined

1. **Auditory considerations**- operation of the MRI coils produces a loud thumping noise. It is important to place earplugs in the ears of the patient undergoing a scan. There have been reports of temporary and permanent hearing loss following MR examinations and the loud noise may also necessitate deeper levels of anesthesia.
2. **Contrast Agents**- The most common MRI contrast agent is gadopentate dimeglumine (Gadollinium), which has a high therapeutic ratio and a low incidence of side effects. Side effects reported include headache, nausea, vomiting, burning at the site of injection and hives.
3. **Ferromagnetic metal objects**- the attractive force of the magnet exerts a substantial pull on ferromagnetic objects and, when free can move objects towards the magnet center with dangerous speed. For example, scissors, pagers and oxygen cylinders become missiles and are all dangerous risks inside the MR Scanner! Individual objects can be tested for ferromagnetism with a powerful hand held magnet outside the scanner prior to bringing them into the magnet room.
4. **Nonferromagnetic metal objects**- even nonferromagnetic implants must be treated with care if they are in close proximity to the region to be scanned. Metal objects can distort the field sufficiently to cause degradation of image quality and the application of intermittent radiofrequency fields to metallic objects can lead to heating and the danger of burns.

Indications for anesthesia and sedation

1. The need for immobility- the MR images are composed of multiple data acquisitions, which are averaged by the computer to give the final image. Some

scans can take 20 minutes while others can require over one hour. Movement of the patient at any point during the scan can degrade the quality of the final image by the production of motion artifacts. Infants and children, and confused or developmentally delayed young adults will not be cooperative during an MRI scan.

2. Patient anxiety- anxiety is a problem that may prevent a patient from going into the scanner. The confined space, the loud noises, the temperature of the magnet and length of the procedure have been found to be the main causes of distress. Sedation has provided a solution to many of these problems.
3. Airway protection- patients who are unconscious, critically ill patients, or patients with head injuries may require tracheal intubation controlled ventilation and anesthesia in order to perform a scan.
4. Anxiety and claustrophobia- some young adults may have a fear of being in a confined space and may not tolerate a scan without sedation or anesthesia.

Guidelines for monitoring pediatric patients during and after sedation or general anesthesia

1. The goals of sedation in the pediatric patients are to:

    - guard the patient's safety and welfare
    - to minimize physical discomfort or pain to minimize negative psychological responses to treatment by providing analgesia and to maximize the potential for amnesia
    - to control behavior
    - to return the patient to a state in which safe discharge is possible

1. Regardless of the intended level of sedation or the route of administration one must remember that sedation may result in loss of the patient's protective airway reflexes. Sedation of pediatric patients has serious associated risks such as hypoventilation, apnea, airway obstruction, and cardiopulmonary compromise. These risks must be avoided or accurately diagnosed and treated appropriately
2. Before sedation it is important to obtain an informed consent explaining the risks involved with the drugs being delivered. NPO status must also be evaluated. No milk or food should be consumed 6 hours prior to the scheduled procedure. Breast milk may be given 3-4 hours prior to the scan and clear liquids (water, apple juice) can be given up to 2 hours prior to the scan. Patients known to be at risk for pulmonary aspiration (e.g. patients with GE reflux, obesity, pregnancy, bowel obstructions etc.) may benefit from treatment to decrease gastric volume and increase gastric pH and require endotracheal intubation.
3. A complete history including age, weight, allergies, relevant past medical history, and any history of previous anesthetics/sedation must also be obtained prior to any sedation or anesthetic.
4. The practitioner who uses sedation must have immediately available the facilities, personnel, and equipment to manage emergency situations. A protocol for access to back-up emergency services should be clearly identified in case immediate help is needed. Equipment must be suitable for children of all ages and sizes being treated. A positive-pressure oxygen delivery system and a functional suction apparatus with appropriate suction catheters must be immediately available both in the scan room and in the preparation room. Equipment for noninvasive blood pressure monitoring and oxygen saturation

monitoring must be available. Airway management and breathing equipment must be checked to make sure they are functioning properly prior to any sedation. An emergency cart must be immediately accessible. The cart must contain equipment to provide the necessary age-appropriate drugs and equipment to resuscitate an unconscious and apneic patient.

Anesthesia for children undergoing MRI

1. The pharmacokinetic properties of propofol make it an ideal anesthetic for children undergoing MRI. Intravenous propofol offers several advantages as an anesthetic for children undergoing magnetic resonance imaging. An intravenous anesthetic without endotracheal intubation allows for careful titration of sedation to achieve a clinical effect and eliminates the need for a nonferromagnetic anesthesia machine. Propofol provides the anesthesiologist with the ability to titrate an anesthetic level rapidly and maintain stable drug concentrations during the MRI procedure, thus ensuring that anesthesia is administered in a timely and consistent manner. Recovery from this type of anesthesia is rapid and not accompanied by nausea or vomiting. Often the anesthetic can be delivered allowing the patient to breathe spontaneously. If there is any difficulty maintaining a patent airway then a LMA can also be used with good effect. In children between 1-10 years of age a dose 100 mcg/kg/min is sufficient to keep the patient asleep with no movement during the scan. If the child has an IV in place then a bolus of 2 mg/kg should be given initially, followed by a continuous infusion of propofol. If no IV is in place then anesthesia can be induced with halothane or sevoflurane (with N_2O and oxygen), an IV can be inserted, and then the continuous infusion of propofol started.
2. General anesthesia with endotracheal intubation may be necessary during MR imaging. Patients with head trauma requiring control of their $ETCO_2$, patients from the PICU who are intubated due to underlying pathologies and infants with histories of apneas and bradycardias are just a few examples of indications for endotracheal intubation. If there is no clear medical reason for tracheal intubation then in most instances spontaneous ventilation is used.

   Several other techniques have been described for anesthetizing/sedating children undergoing MRI. Oral or rectal administration of hypnotic drugs is commonly used in younger children. Intramuscular or intravenous ketamine or barbiturates may be used in older children. Oral, rectal, and intramuscular methods of drug administration are affected adversely by the unpredictable onset and depth of anesthesia, discomfort associated with drug administration, and prolonged recovery periods. At Stanford, a nurse trained in the administration of these drugs as well as airway management often provides sedation for the MRI. For children less than 2, chloral hydrate is often used if the child does not have an IV in place. In children older than 1 who have an IV, Nembutal is often used in a dose of 4-6 mg/kg. If the child is over 2 and does not have an IV, then an IV is inserted and Nembutal is given

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