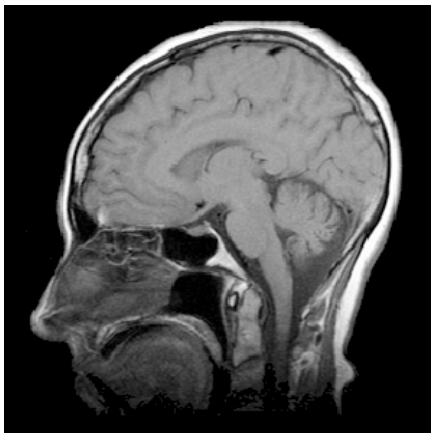

Anesthesia and Airway Management in the MRI Suite

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CASE PRESENTATION: PART I

Mr. Soprano is a 52 year old entrepreneur in the waste management industry. He weighs 119 kg, is 175 cm tall, and is being investigated for "dizzy spells" that appear to be panic attacks. His medical problem list includes obesity, untreated hypertension, and possible obstructive sleep apnea (based on his wife's nocturnal observation that "sometimes he just stops breathing"). When questioned, he admits to extreme claustrophobia, possibly the result of a protracted period of time spent in a car trunk. A previous attempt at a magnetic resonance imaging (MRI) scan was unsuccessful because Mr. S, startled by the onset of the load noises made by the MRI machine, panicked and tried to get out of the MRI scanner, pulling out his IV in the process.

On this occasion, the MRI team decided that Mr. Soprano might be more cooperative with pharmacologic assistance, and to this end gave him 5 mg of IV midazolam (Versed ®). Unbeknownst to the clinical team, just before entering the MRI suite Mr. Soprano had also taken 6 mg of sublingual lorazepam (Ativan ®) to help reduce his considerable anxiety. For the scan, a pulse oximeter and nasal capnograph were used to monitor respiration. Oxygen was administered by nasal prongs at 3 liters per minute.

About 10 minutes into the scan the pulse oximeter alarm went off, drawing attention to an oxygen saturation reading of 83%. The pulse oximeter waveform quality appeared to be good. However, no waveform could be obtained from the capnograph. Since Mr. Soprano was deep inside the MRI machine, it was hard to see how well he was actually breathing. You were summoned to the MRI suite to help manage this patient.

THE MRI SUITE

What is MRI and Why is it Done?

Magnetic resonance imaging (MRI) has steadily increased in popularity as a non-invasive, painless diagnostic imaging procedure. MRI images are produced using a strong (typically, 1.5 Tesla [15,000 Gauss]) magnetic field into which radiofrequency (RF) pulses are injected. MRI is the imaging method of choice for examinations in which water content differences make it possible to differentiate tissue types [1]. It offers distinct advantages over computed tomography (CT), both in terms of the quality of the obtained images for certain types of tissue (like brain), and in the lack of exposure to ionizing radiation. MRI scans are frequently ordered by neurologists and neurosurgeons for patients of all ages with neurological disorders. In addition to intra-axial pathology, orthopedic problems such as osteomyelitis, soft tissue muscle tumors, and damaged knee menisci can be assessed using MRI techniques [1].

What is Unique About the MRI Suite?

The extreme strength of the magnetic field in a MRI scanner can be hazardous. For example, patients with implanted ferromagnetic objects like aneurysm clips have had these fatally pulled out of position by the magnetic field [2]. Similarly, some authorities have expressed concerns about carrying out MRI scans in patients with pacemakers [3]. Likewise, ferromagnetic objects like wrenches, scissors, IV poles, pens, stethoscopes, and even hair barrettes can become accidental projectiles. In one case, a pillow containing metal springs not detectable using a handheld magnet flew into the magnet during positioning of a patient, fortunately without causing injury [4]. Sometimes death has been the result, as in the case of a 6 year old boy killed when a loose oxygen tank crushed his skull [5 - 7]. In addition to this, the strong magnetic field and associated radio frequency pulses can interfere with the operation of ordinary anesthesia machines as well as with patient monitoring equipment, sometimes even resulting in patient injury [8].

Zimmer et al. [9] relate the following interesting cautionary tale. A 2-yr-old boy underwent abdominal MRI scanning under general anesthesia. During the case, the anesthesia nurse carried a portable sevoflurane vaporizer into the MRI suite. When she put the vaporizer on the examination table it was vigorously attracted toward the scanner, and it was only by the strength of two people that the vaporizer was directed to strike against the gantry instead of flying directly into the magnet, where it might have hit the child. Quenching the magnet, *i.e.*, emergency release of liquid helium from the scanner to collapse the magnetic field, was initially considered, but the vaporizer could be removed with the help of a third individual. Of interest, immediately after the mishap the portable vaporizer was tested for magnetism with a strong handheld magnet, where no attraction was apparent. A review of the event revealed that the vaporizer contained ferromagnetic material in the temperature compensation module.

It should be emphasized that allegedly MRI-compatible anesthesia machines and patient monitors may still contain ferromagnetic components and may pose risks when safety precautions (often described in fine print in the user's manual) are violated.

Why Might MRI Imaging Require Moderate or Deep sedation, or General Anesthesia?

During MRI scans patients must remain motionless. However, the long duration (up to 20 minutes or more) of some MRI scans may eventually lead to severe discomfort for many patients, the result being blurred images should the patient move in order to get comfortable. In addition to fidgeting, many MRI patients are fearful or claustrophobic. Moderate to deep sedation or general anesthesia may be required to immobilize these patients sufficiently to obtain a good scan, particularly children and the mentally challenged.

What Special Precautions Must Clinicians Take When Responding to or Working in the MRI Suite?

Clinicians caring for patients in MRI suites must be careful to rid themselves of all objects with possible ferromagnetic components such as pagers, mobile phones, keys, pens, stethoscopes etc. prior to entering. In addition, credit cards and ID badges may be erased. Another issue concerns the clinical monitoring available in an MRI unit. Those MRI facilities that wish to utilize full monitoring for patients undergoing general anesthesia have available to them for purchase MRI-compatible systems that support automatic noninvasive blood-pressure monitoring, electrocardiography, pulse oximetry, capnography and even multichannel invasive pressure monitoring. When electrocardiogram electrodes are used for monitoring, these need to be positioned away from the imaging area, or (in special cases) should be replaced with special carbon MRI-compatible electrodes.

Where Can One Obtain MRI-compatible Anesthesia Equipment?

The list of MRI-compatible anesthesia equipment needed in an MRI suite can be extensive, and includes anesthesia machines, patient monitors, oxygen cylinders, laryngoscopes etc. Your purchasing department should be able to help you here. I also recommend spending some time on the Web, starting at http://www.magmedix.com Additional resources appear in Appendix 1 below.

AIRWAY MANAGEMENT CONSIDERATIONS IN AN MRI UNIT

What airway equipment may or may not be used in an MRI unit?

The answer to the question regarding which airway management devices are safe to use in an MRI unit can be both simple and complex. The simple answer is that devices such as conventional laryngoscopes that contain substantial amounts of ferromagnetic materials can easily become dangerous projectiles, while items completely free of ferromagnetic materials are completely safe. The complex answer is that most airway instrumentation that has not been specifically designed for use in an MRI environment is likely to have at least some ferromagnetic components. Even apparently benign products like endotracheal tubes and laryngeal mask airways may have small amounts of ferromagnetic materials, such as metallic springs in the cuff inflation valve. (While such small ferromagnetic objects do not generally present a projectile safety hazard, they can interfere with the image quality, possibly introducing an “information hole” if located near the imaging area.)

What are some other airway management issues in the MRI environment?

Since most airway devices are not specifically designed for the MRI environment, equipment like flexible fiberoptic bronchoscopes, rigid fiberoptic laryngoscopes such as the Bullard laryngoscope or video laryngoscopes such as the GlideScope must be specifically tested for suitability in the MRI environment by experienced MRI personnel. In addition, there is a theoretical concern that armored endotracheal tubes and other airway devices with wire-reinforced elements may either interfere with image quality or undergo self-heating from absorbed electromagnetic radiation.

It should also be pointed out that airway equipment that contains electronic circuits can be theoretically affected by strong magnetic fields, for example by the mechanism of closing a normally open switch containing ferromagnetic elements. (This has been alleged to sometimes occur with the Trachlight® intubating lightwand).

MANAGEMENT OF THIS PATIENT

What are the immediate management options for this patient?

Let's get back to Mr. Soprano, who is now turning blue. Chances are very good that he has been oversedated and has obstructed his airway, based on the history from his wife that he sometimes "just stops breathing" while asleep points to the probability that obstructive sleep apnea (OSA) is involved. Here are the management options available to us:

1. If the patient is accessible, a simple jaw thrust or head tilt often suffices to restore respiration. Most of the time, however, the scan will have to be temporarily suspended to permit this to occur. (This does not, however, mean that the magnet needs to be turned off). Some individuals have tried taping the patient's jaw to the MRI head frame to help keep the airway open.

2. The patient may also benefit from a nasopharyngeal airway. An oropharyngeal airway may also be considered, but these tend to be less well tolerated by the patient.

3. If a simple jaw thrust, head tilt or artificial airway does not promptly do the job, positive pressure ventilation with 100% oxygen using a bag/mask system may be needed to restore oxygenation. Of course, when the patient is severely hypoxemic, this should be the first step undertaken.
4. Pharmacologic reversal of the lorazepam / midazolam may be helpful to reduce the level of sedation and restore the airway. Intravenous flumazenil, administered in 100 microgram increments in adults, is a benzodiazepine antagonist that works for both lorazepam and midazolam. In cases where opiates such as fentanyl are used, pharmacologic reversal can be achieved using intravenous naloxone (Narcan ®), also using 100 microgram increments. Bear in mind that since both naloxone and flumazenil have relatively short durations of action, resedation can still occur. A final consideration to bear in mind is that if Mr. Soprano is a chronic user of benzodiazepines he may be physically benzodiazepine dependent and flumazenil in administered traditionally recommended doses may induce seizures [10].

5. In extreme cases, insertion of a Laryngeal Mask Airway (LMA) or even tracheal intubation may be necessary. While the tiny metal spring often present in the valve of an endotracheal tube or LMA cuff inflation lines does not present a concern, use of traditional ferromagnetic laryngoscopes in this setting is fraught with safety hazards. Fortunately, as noted earlier, MRI-compatible laryngoscopes are commercially available, along with MRI-compatible batteries, and should be readily available when it is anticipated that intubation at a location close to the MRI scanner may be necessary.

CASE PRESENTATION, PART II

Given that Mr. Soprano has developed respiratory difficulties, it is decided to remove him from the scanner to allow for positive pressure ventilation or other intervention. With the commotion of being moved about, Mr. Soprano becomes aroused, and spontaneous respirations resume. Instead of positive pressure ventilation with an Ambu bag, since adequate spontaneous respirations have ensued, a nonrebreathing facemask is used, and the pulse oximeter is soon providing reassuring tones and numbers. Mr. Soprano is still drowsy when left alone, however, and continues to intermittently obstruct his airway. The radiologist is eager to have the scan completed, emphasizing first that Mr. Soprano's neurologist has called repeatedly about the results - being concerned about ruling out a brain tumor – and also emphasizing that this is the second time Mr. Soprano has undergone a MRI scan attempt.

You examine Mr. Soprano's airway. Only the uvula is visible (Mallampati III classification). In addition, his considerable obesity and his apparent history of obstructive sleep apnea raise red flags regarding possible difficulties with mask ventilation, with laryngoscopy and intubation, with carrying out an emergency surgical airway should one become needed. In addition, patient issues regarding cooperation, possible substance abuse, and an increased potential for rapid desaturation (because of a small functional residual capacity (FRC)) are all prospective concerns. Given these issues, how do you want to proceed now?

How should we proceed (if did we proceed) with managing the airway?

This patient has a possible difficult airway from many perspectives. Given his obesity, chances are that he would be fairly difficult to ventilate by mask, and given his Mallampati score of III and his size he might well also be difficult to intubate using a regular laryngoscope. His size also suggests that insertion of a supraglottic airway device might be more difficult than ordinary and certainly suggests that an emergency surgical airway would be more difficult than usual. In addition, his obesity means that his FRC is smaller than it would otherwise be, with the result that oxygen storage in the lungs is reduced, leading to early desideration with apnea.

Under the assumption that there is some urgency to proceed and that canceling the case is not an option, a variety of means to secure the airway can be considered. The first option ("Plan A") might to induce anesthesia using propofol and achieve muscle relaxation using succinylcholine. This would either be done in the induction area some distance from the MRI scanner, or even in a regular operating room. Naturally, this option assumes that generous preoxygenation has been given, that expert help is at hand (a second pair of skilled hands is always appreciated when things don't go as planned), that a rich variety of airway devices and adjuncts like the "gum elastic bougie" and the laryngeal mask airway are immediately at hand, and that the patient is not prone to aspiration. (The reason that succinylcholine rather than longer acting muscle relaxants like rocuronium is recommended is that should intubation ultimately prove to be impossible, it will take less time for the patient to resume spontaneous respiration.)

If the view at laryngoscopy proves to be unsatisfactory to the extent that ordinary interventions such as external laryngeal manipulation or use of the gum elastic bougie are unlikely to be successful, my recommended "Plan "B" would be to use a GlideScope, an instrument that in my experience (of over 1000 cases) has proven to be especially valuable. My "Plan C" would be to use fiberoptic intubation, either while the patient is still under general anesthesia or after waking up the patient. There are several possible variations of such a plan, such as inserting a laryngeal mask airway (LMA) and intubating fiberoptically through the LMA with the aid of an Aintree catheter [11] or intubating fiberoptically using the GlideScope to facilitate the process [12].

If one's overall clinical impression is that inducing general anesthesia is not a prudent course, a more cautious approach would likely be awake intubation, for instance using traditional flexible fiberoptic methods or even awake intubation using the GlideScope [13].

Post Intubation Management

At the end of the procedure a decision should be made whether it is safe to extubate the patient in the MRI suite, whether it is better to extubate the patient in the PACU after a period of elective ventilation (as might be appropriate if intubation was difficult and it is suspected that the airway structures are edematous), or whether extubation over a tube exchanger might be a wise precaution.

OTHER CONSIDERATIONS

How do you manage a patient with a history of difficult airway in the MRI suite?

A review of the patient's previous medical records (especially anesthesia records) can be valuable to determine why previous intubation attempts may have been difficult. Depending on what information is found in the medical records and the results of the airway examination, options will range from maintaining spontaneous ventilation in the patient in a setting of minimal sedation to full general anesthesia preceded by awake endotracheal intubation. In particular, patients with severe reflux may require rapid sequence intubation or awake intubation methods to prevent aspiration from occurring.

WHAT ARE THE TAKE-HOME MESSAGES?

The key message is that the MRI suite is a potentially hostile environment for the patient with a difficult airway and that numerous special precautions must be taken to prevent airway-related troubles in such patients. Such precautions include having an extra pair of skilled hand available to help, having primary and secondary backup plans for airway management and knowing in advance what equipment can or cannot be used near the MRI scanner. Because it can be difficult to directly observe patient's breathing when they are deep in the MRI scanner, other means of respiratory monitoring (such as capnography) are especially important. In some cases patients will need to be intubated because of the high likelihood of airway obstruction with sedation; in such cases consideration must be given to the possibility that the patient may be difficult to intubate without special equipment and / or special techniques.

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APPENDIX

Where Can I Get More Information on MRI Safety Issues?

A good place to start is on the Web at http://www.mrisafety.com. Unfortunately, one must register to use this site. Another valuable resource is from the American College of Radiology Blue Ribbon Panel on MR Safety. This site offers a number of useful safety guidelines and clinical protocols and can be accessed at http://www.acr.org/dyna/?doc=committees/mr_safety/safe_mri.html

An interesting report from the Institute for Safe Medication Practices (http://www.ismp.org/msaarticles/burnsprint.htm) explains that patient burns can occur when medication patches employing an aluminized backing are used (like many of those in common use containing nicotine, nitroglycerine, scopolamine etc.). (What happens is that the radiofrequency (RF) pulses heat up the metal involved, even if the metal is not ferromagnetic.) Of interest, this problem can also occur when patients have tattoos using metal pigments.

A comprehensive list of MRI-forbidden objects is available at http://www.newmri.com/html/mr_safety.asp