MRSO Exam Prep Course

Module 2

Biological Effects of the Static Magnetic Field

In the previous module, we discussed the fundamental physical properties of static magnets. Now, we are going to focus on biological reactions to persons coming within close distances of the static magnet. In this module, we are going to focus on:

- ✓ Magnetophosphenes
- ✓ Magnetohydrodynamic effect
- ✓ Vertigo, dizziness/nystagmus, and nausea
- ✓ Teratogenesis

Section 2.1 Magnetophosphenes

Think about the blood that is traveling through your body. As the blood moves through your body, it also carries its ions. An ion can be grouped as a cation (ions that carry a net positive charge) or an anion (with a net negative charge). This means your blood has a small electrical current running through it based on its chemical makeup. As we approach a static magnetic field, the strength of the magnetic field will increase. This changing magnetic field creates a sensation in our bodies due to the electrical field naturally produced in our bodies, and can induce a current in the retina, stimulating the optic nerve. Because of this, the patient may experience a flashing light sensation in their vision. These flashing lights are called magnetophosphenes. The intensity of magnetophosphenes depends on the rate of change of the magnetic field over time. Rapid movements over magnetic gradients can cause dizziness, nausea, and nystagmus, which is an involuntary eye movement.

QUESTION:

A patient is excited about having the MRI scan. They are so excited they ran into the scanner room towards the MRI unit. As they approach the magnet, the patient's eyes shift in all directions, looking at the medical devices around the room, the ceiling, the floor, and the walls. As an MRSO, what would you describe as happening?

ANSWER:

As the patient is running, they are moving at a fast rate towards the magnetic field. So, the magnetic field is changing much more rapidly. Faraday's Law suggests you can induce electrical current based on a changing magnetic field. The greater the change, the greater the induced electrical current. This means the more significant the electrical current rendered on the patient's retinas. Like the patient moving toward the magnetic field, as the patient's eyes move around the room, they also induce an electrical charge in the retinas. The probability for the patient to experience magnetophosphenes in this situation is very high.

Section 2.2 Magnetohydrodynamic Effect

Magnetohydrodynamic (MHD) effect studies electrically conducted fluids as they are in motion. Similar to magnetophosphenes, we are discussing the electrically charged motion of blood moving through your body; however, instead of focusing on the vision with magnetophosphenes, MHD focuses more on the blood flow itself in high static magnetic fields. More importantly, the main difference between magnetophosphenes and MHD is that MHD focuses on induced electric currents produced while the patient is not moving, and magnetophosphenes focus on the changing magnetic field as the patient moves through the field.

The induced elevated voltage in our blood while in the static magnetic field can contaminate the EKG (electrocardiogram) signal, recorded simultaneously during an MRI scan for synchronization purposes. Image 2.1 depicts the EKG of a typical human heart rhythm, and the red triangles show how the magnetic strengths of a 1.5 T and a 3.0 T MRI effect the T-wave. The high voltages generated in the patient's body will increase the amplitude of the T-wave. Because of this elevated T-wave, it will hinder the correct R-peak detection. This causes no harm to the patient but can create artifacts during imaging. MHD occurs when the patient is sitting still during the scan. It can cause artifacts in the imaging due to elevated T-waves, and the stronger the static magnet is, the stronger the MHD-induced voltage will be on the patient. The stronger this MHD-induced voltage, the higher the elevated T-wave. The higher the elevated T-wave, the more distorted our image may become.

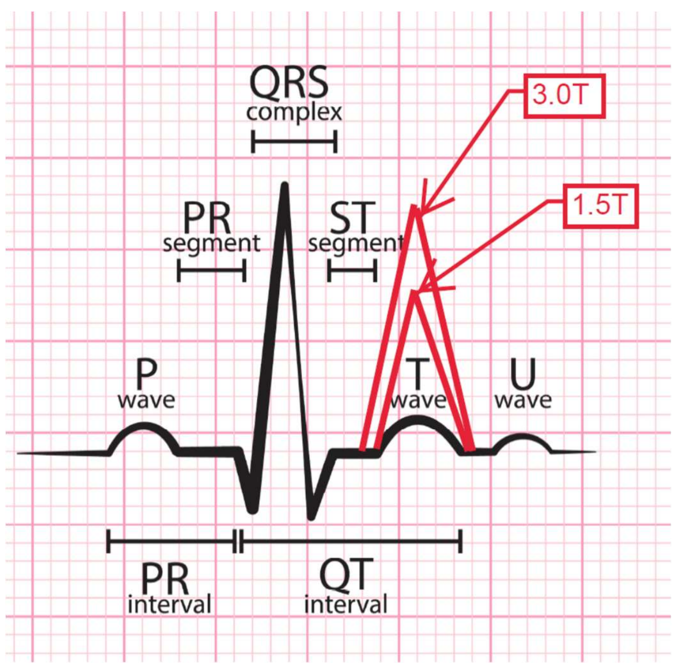

Image 2.1 EKG of a Heart in Normal Sinus Rhythm

QUESTION:

What is the difference between **magnetophosphenes** and the **magnetohydrodynamic effect**?

ANSWER:

Magnetophosphenes occur when a person travels rapidly through the spatial magnetic gradient. Such drastic changes in the magnetic field increase the patient's potential for involuntary eye movement.

The **magnetohydrodynamic effect** occurs when the patient is not moving. However, blood is flowing through the patient while they are still. This fluid is electrostatically charged and can create elevated amplitudes in the T-wave. This can potentially create artifacts in our patients.

Section 2.3 Vertigo, Dizziness/Nystagmus, & Nausea

Flow potential is a significant contributor to most of the biological effects experienced by a patient as they enter the MR environment. When we think about a patient experiencing vertigo, dizziness, and nausea in the MR environment, we must consider how the static magnetic field affects the fluid circulating in the inner ear's balance center. Per our discussion on the MHD effect, we know that the fluids in our bodies have electrically charged ions moving through us and that the static field slightly changes the behavior of these fluids as they come into the static magnetic field. The stationary magnet will push on the inner ear fluid, resulting in a patient feeling unsteady movement. This can result in the symptoms discussed in this section. The stronger the static magnetic field, the higher the patient's probability of feeling this discomfort. These symptoms can be reduced if we slowly acclimate the patient to the MR environment, take slower steps when approaching the magnetic field, and take a direct path. Ensure the patient is calm; nervous patients will have an increased pulse, increasing their blood flow. Faster heart rates lead to an increase in induced electric currents in their bodily fluids.

Image 2.2

Section 2.4 Teratogenesis

Teratogenesis refers to the process of the development of congenital abnormalities in an embryo or fetus. There is limited understanding about the effects of the MR environment on a developing fetus. Some studies have been undertaken to investigate the potential impact of MRIs on the fetus when it is used as a diagnostic tool during pregnancy.Four potentially adverse effects have been found:

1) The impact on auditory development is due to the acoustic sound made by the resonator.
2) Teratogenic effects on DNA.
3) Physical deformities secondary to temperature increase.
4) Teratogenic effects due to using gadolinium as a contrast agent.

The research suggests that there may be potential risks associated with MRI exposure during early pregnancy. For instance, in mouse studies, MRI exposure during mid-gestation resulted in a reduction in crown-rump length and caused eye malformations in a genetically predisposed mouse strain. Additionally, exposure of chick embryos to strong static magnetic fields and rapid electromagnetic gradient fluctuations in the first 48 hours of life led to an increased number of dead or abnormal chick embryos when examined at day 5.

The potential mechanisms for these effects include the heating effect of MR gradient changes and direct non-thermal interaction of the electromagnetic field with biological structures. It's important to note, however, that tissue heating is greatest at the maternal body surface and approaches negligible levels near the body center, making it less likely for thermal damage to occur to the fetus. However, consider that a human body is much larger than a mouse and a chick.

Although some critics argue that these studies may not be directly translatable to humans, they still raise valid concerns. As a result, a cautious approach should be taken when considering fetal MRI in the first trimester, especially considering the relatively high rate of spontaneous abortion during this period.

From a practical perspective, it is generally recommended to avoid MRI during pregnancy, particularly for elective studies or during the first trimester. However, if medically necessary, MRI remains preferable to any studies involving ionizing radiation due to the potential risks associated with the latter.

Section 2.5 Pregnancy-Related Issues

The use of MRI on pregnant patients had significant technical issues at first, particularly due to the existence of picture deterioration caused by fetal movements. Several technological advancements, such as the creation of high-performance gradient systems and quick pulse sequences, have given significant gains in imaging pregnant patients. As a result, high-quality MRI investigations for obstetrical and fetal purposes can now be performed routinely in the clinic. Because of the importance and ubiquity of MR operations in pregnant patients, it's critical to grasp the technology's safety features as well as the potential bioeffects of the electromagnetic fields employed in MR.

Image 2.3

2.5.1 Pregnancy and MR Safety

Diagnostic imaging is frequently used in pregnant patients. As a result, it's not surprising that the subject of whether or not a patient should have an MR operation while pregnant regularly arises. Unfortunately, there have been far too few studies looking into the relative safety of MR techniques in pregnant women. The main safety concerns are:

- The MR system's static magnetic field's possible bioeffects
- The dangers of being exposed to the gradient magnetic field
- Radiofrequency (RF) electromagnetic fields can cause harm.

Image 2.4

2.5.2 Clinical Applications of MR Procedures in Pregnant Patients

Brain and Spine Imaging: The brain, spine, body, and musculoskeletal disorders that affect pregnant women are like those that affect non-pregnant women. In addition, pregnancy-related disorders such as toxemia and sagittal sinus thrombosis can arise. During pregnancy, pituitary adenomas may grow. Medical imaging is obviously frequently needed to assess and manage patients with these disorders. Because MRI does not use ionizing radiation, it is an excellent alternative to computed tomography (CT), particularly in circumstances when ultrasonography is inadequate or inappropriate.

Brain Imaging: Aside from pregnancy-related brain diseases, common cerebral conditions such as tumors, infarctions, hemorrhages, arteriovenous malformations, and aneurysms can arise during pregnancy. MRI examination is the best way to assess these. MR contrast compounds should be used only in individuals who require prompt diagnosis (i.e., metastasis) or therapy (i.e., brain tumor therapy prior to surgery).

Spine Imaging: MRI should only be used in the case of suspected disc protrusion, which would need surgery during pregnancy. MRI can also be used to assess a spinal tumor, an unstable fracture, an infection, a syrinx, or an arteriovenous (AV) malformation, all of which could alter urgent therapy or administration modality (cesarean section vs. vaginal delivery).

Head and Neck Imaging: Because it does not use ionizing radiation and does not require the use of contrast agents, an MRI of the head and neck may be preferable to CT.

Chest and Cardiovascular Imaging: Without the use of ionizing radiation or contrast chemicals, MRI can easily reveal the hilar and mediastinal nodes. In pregnant patients, cardiovascular MRI is good for demonstrating and confirming abnormalities such as aortic coarctation, aortitis, aortic dissection, and atrial myxoma. Echocardiography is still the gold standard for non-invasive heart imaging, especially in pregnant patients.

Abdominal Imaging: Sonography is the preferred method of abdominal imaging in pregnant women, especially to check for hepatobiliary and renal diseases. MRI has a benefit over CT in terms of evaluating the liver, pancreas, and retroperitoneum because it does not use ionizing radiation. MRI can clearly identify large lesions such as tumors, pseudocysts, and abscesses.

Musculoskeletal Imaging: The use of MRI in the evaluation of musculoskeletal problems in selected patients who require intervention during pregnancy is beneficial. Routine knee and shoulder exams can usually wait until after birth, but the evaluation of a suspected infection or neoplasm must usually be done right away.

Guidelines for the use of MR techniques in pregnant patients are as follows: MRI scans can be performed in pregnant patients to address serious clinical issues or to control potential risks to the patient or the fetus. A verbal and written informed consent approach should be used for the MR operation. The pregnant patient should be advised that there is not sufficient evidence that using clinical MRI during pregnancy has any negative consequences.

MRI use for pregnant patients should not be avoided in the following circumstances:

- Imaging is required for patients who have active brain or spine symptoms.
- Imaging is required for cancer patients.
- Patients with active illness signs and symptoms in the chest, abdomen, and pelvis when sonography is non-diagnostic.
- In circumstances where a prenatal abnormality or a complicated fetal condition is suspected.

Image 2.5

2.5.3 Pregnant Healthcare Workers in the MR Environment

The main source of exposure for a pregnant healthcare worker in the MR environment is a static magnetic field, with the biggest factors being duration and distance from the magnet. Specifically, the pregnant technician may be exposed to a static magnetic field of several hundred gausses or more for extended periods of time each working day. However, this level of magnetic field exposure is not thought to be harmful to the embryo or fetus.

The following should be considered when it comes to pregnant healthcare workers and the MR environment:

- Occupational exposure to static magnetic fields has not been proven to raise the likelihood of bad outcomes in pregnant MRI technologists.
- Pregnant MR healthcare workers should spend as little time as possible in the MR system and the room itself, especially if they are performing interventional or MR-guided treatments.