Mira Liu

Imaging Practicum 1: MRI 1

Due August 20th

**Introduction and overview of MRI**

**MRI Introduction:**

Magnetic Resonance Imaging (MRI) is a medical imaging technique that uses magnetic fields and nuclear spin to generate images of anatomy and physiology of the body. MRI does not use x-rays or ionizing radiation like in CT and PET; instead, MRIs in most clinical facilities use 1.5T and 3T magnetic fields, and the strength of these magnetic fields influence the nuclear spin of hydrogen atoms in the human body. When a patient is in the main magnetic field the spins will align parallel or anti-parallel the magnetic field. The resulting net alignment of spins along the main magnet creates signal, with the alignment and signal increasing as field strength increases. These nuclear spins have nuclear magnetic moment that precesses about the main magnetic field at a specific Larmor frequency. Using different strengths of magnetic fields and combinations of magnetic field gradients and radiofrequency pulses, images can be formed with tissue differentiated based on different relaxation times and responses to the magnetic field.

**MR Clinical use and Risks:**

MRI can be used for both anatomic and physiologic imaging. Common uses are neuroimaging for tumors, MR angiography, and functional MRI which in theory uses the difference in magnetic properties of oxygenated and deoxygenated blood to determine activity in the brain. Clinical MRIs in the US are typically high field superconducting magnets which require liquid helium to sustain superconductivity and keep the current high enough to maintain the main magnet. Low field MRIs can be used, be open for claustrophobia, and portable, and without the need for helium, at the cost of lower resolution. High temperature superconducting wires are another potential alternative to avoid the cost of liquid helium.

While an MRI is noninvasive and does not involve x-rays or ionizing radiation, there are health risks regarding metals. Diamagnetic and paramagnetic materials can be temporarily weakly magnetized resulting in some magnetic susceptibility. This causes disturbances in the magnetic field and some change in signal through susceptibility artifacts. One example of imaging that uses this trait is gadolinium contrast agent which is a paramagnetic agent that shortens T1 leading to brighter signal in the image. On the other hand, ferromagnetic materials are permanently magnetized and have a large magnetic susceptibility in which the magnetic field in the materials is greatly increased. As ferromagnetic material is strongly attracted to the magnetic field, no ferromagnetic materials should be brought into the MR room. For example, bullets and shrapnel are often ferromagnetic meaning one who suspects any such exposure must undergo a CT or x-ray before hand to ensure patient safety.

**MR Hardware:**

An MRI patient is located on a table in the center with the RF coil closest to the patient followed by magnetic gradient coils, the shim coils, and then the superconducting primary electromagnetic coil for the main field. The RF coil transmits and receives RF signal and so are closest to the patient. The magnetic gradient coils induce magnetic gradients along the x-axis, y-axis, or along z-axis of the main magnetic field for frequency encoding, phase encoding, and slice selection. The shim coils carry smaller current to provide auxiliary magnetic fields to eliminate inhomogeneities in the main magnetic field of the MR system. Lastly, the primary electromagnetic coil forms the main homogeneous magnetic field along the bore of the MRI.

**RF pulses and relaxation times:**

RF pulses applied at the Larmor frequency of the nuclear spin lift the spins from a lower energy state to a higher one. MR signal is then measured in the x-y transverse plane, where maximum signal is measured when spin is collectively flipped 90 from alignment along the main bore. The spin’s relaxation is comprised of spin-lattice relaxation and spin-spin relaxation. Spin-lattice relaxation follows T1 decay in which signal in the transverse axis is lost as the spin re-aligns with the main magnet along the z-axis. Spin-spin relaxation follows T2 decay in which signal in the transverse axis is lost due to dephasing. The signal equation is then given by the combination of the two

TR represents repetition time and TE represents echo time. Repetition time is the length of time between a series of repeating pulses and echoes while echo time represents the time from the RF pule to the echo. T1 weighted images are formed with a short TR and short TE to show regrowth along the z-axis after a certain flip angle while minimizing spin-spin decay, while T2 weighted images are formed with long TR and long TE to maximize spin-spin decay. A T1 image can be distinguished by dim fluid, and bright fat, while a T2 image contains bright fluid and dim fat. Radiologists often use both when making clinical diagnoses.