X-RAY / IMAGING / MRI

Keeping Up With Western Medicine Advancements: The Amazing World of Imaging Studies

Bruce H. Robinson, MD, FACS, MSOM (Hon)

When patients with neuromuscular problems come to you for treatment there is usually a lot you can do for them to improve their mobility or reduce their pain, whether it is a middle age woman with a frozen shoulder, a young athlete with a partially torn rotator cuff, an elderly man with spinal stenosis in his lower back or his cervical spine, or a runner with knee or foot problems. Many of these patients have also been worked up in a Western healthcare facility and they have had x-rays, MRI scans, or CT scans.

Your patients may also have had other medical problems that have been worked up with other imaging studies of their lungs, heart, kidneys, liver, or perhaps their brain. This article has the goal of possibly enhancing your understanding of these vitally-important diagnostic studies in Western medicine, including some rather amazing cutting-edge new technology.

Imaging studies have been around for 118 years, since the first x-ray machine was invented in 1895. Vast improvements in the accuracy of imaging studies have occurred in the past 33 years since the introduction of CT scans in 1980. There are now 75 million CT scans taken every year in the U.S. (one for every 4 people). These scans have ionizing radiation which can damage DNA. Some oncologists attribute 1% of new cancers to patients' previous CT scans, and they say this rate will rise. However, the tradeoff value of benefits versus risks are often worth it, as for example CT scans in stroke patients, because the treating physician has to know if it is a hemorrhagic stroke or an ischemic stroke. The treatment for the two kinds of strokes is totally different, and a CT scan is required to determine this. MRI's, however, are safe, with no ionizing radiation, although they are less convenient and more expensive. All in all, the diagnostic benefits of imaging studies are truly phenomenal.

X-rays

X-rays were first discovered by Wilhelm Röentgen in1895. His first x-ray was of his wife's hand, showing all the bones inside. This image, developed like a regular photograph, must have seemed astounding to both of them. His discovery revolutionized the diagnostic capabilities of medicine, allowing us to look inside the body for the first time without having to cut it open. Röentgen recorded that he was filled with wonderment as he realized that this discovery could change mankind for the better, long into the future.

Electromagnetic Spectrum

To understand x-rays and other imaging studies, we need to review the electromagnetic spectrum. The terms light, electromagnetic waves, and radiation all refer to the same physical phenomenon: electromagnetic energy. There is a vast range of this wave-like energy, ranging from radio waves on one end of the spectrum that have waves that can be a half-mile in length, to microwaves, that are one centimeter in length, then on to infrared rays, then to visible light in red, orange, yellow, green, blue, purple, and violet. From there the spectrum goes to ultraviolet, then x-rays, and finally gamma waves. The waves of x-rays are so small and fast that they can penetrate human tissue to variable degrees, but are blocked by bone tissue. This variability in penetration goes through the body and strikes a photographic plate, thus taking an x-ray picture of the body, including the tissue fluids, the soft tissues of variable densities, and the bones.

Moving along the electromagnetic spectrum from long to short wavelengths, energy increases as the wavelength shortens. If you hold a 10-foot jump rope with another person and hold it firmly but not absolutely tight, you can create waves in the rope by snapping it with your hand. To create a lot a waves in the rope at the same time you have to snap harder than you do if you only create one or two waves. Gamma rays, at the far end of the electromagnetic spectrum, are very short, extremely fast, and have very high energy. They can be focused and are now utilized for radiation treatment of certain cancers.

CT Scans

CT scan (computerized tomography scan) involves the use of a special x-ray machine that moves around the patient and takes multiple images or slices through the body in various planes. "Tomos" means "to cut or slice" in Greek, and a tomogram is a picture of a slice. The scanner's computer analyzes the information and creates accurate images, especially useful for the head, chest, and abdomen.

The images are generally in standard planes: frontal (coronal), sagittal (sideways slices) and horizontal (axial; transverse). Some CT's and MRI's are now 3-dimensional and some are in color. CT scans give the patient increased radiation over a standard x-ray but the information retrieved is often of vital importance and is usually considered worth the trade-off. However, in a situation where either a CT scan or an MRI can be obtained to study some part of the body an MRI is definitely safer in the long run.

MRI Scans

MRI scan (Magnetic resonance imaging scan) is a scan which creates a high-power magnetic field within the body. The MRI machine then analyses with a computer how the various tissue cells that have been polarized by the strong magnet react to radio waves of differing frequencies administered to the patient (who wears ear muffs or head phones). Accurate pictures of the tissues within the body are thus created without the use of ionizing x-rays (again, A CT scan uses ionizing x-rays).

The strong magnetic field polarizes all the trillions of cells in the body, focusing on the hydrogen in all the water molecules. These water molecules then respond differently to radio frequency pulses, and this is analyzed as a picture. MRI's are more expensive, more time-consuming, noisier, and more claustrophobic than CT scans…but they are safer and often produce better images where fine detail is needed (e.g. the diagnosis of a torn rotator cuff of the shoulder).

CT scans are often better for parenchymal disease in lung and other organ tissues. MRI scans are better for mediastinal and hilar disease of the chest, and far better for musculoskeletal disorders. In large medical centers, CT and MRI scans are often utilized together to obtain as much information as possible.

Radioactive Lung Scans

There are two types:

Perfusion lung scans (Q scans), in which a radioisotope is injected into the bloodstream and it documents any blockages in the pulmonary vessels (especially utilized to diagnose pulmonary embolism).

Ventilation lung scans (V scans), in which a radioisotope tagged gas (Xenon) is breathed into the lungs by the patient. This scan documents any poorly ventilated or unventilated areas in the broncho-alveolar respiratory tree. This kind of scan is able to show pneumonia or severe pulmonary fibrosis.

Lung scans - results:

- Pulmonary embolism: abnormal perfusion scan and normal ventilation scan.
- Parenchymal lung consolidation (pneumonia, for example): normal perfusion scan and abnormal ventilation scan.

Pulmonary angiograms:

In a standard pulmonary angiogram, a radioactive dye is injected into the pulmonary artery. This must be done through a catheter that has been passed up inside the chest from the femoral vein, or down into the pulmonary artery from the jugular vein in the neck or the subclavian vein in the upper chest. This invasive test is usually done by a specially-trained interventional radiologist. For many years this test has been the "gold standard" for diagnosing pulmonary embolism, especially in a difficult- to- diagnose patient with lung disease as well as a pulmonary embolism. The angiogram accurately reveals any areas where there are blockages in the blood flow due to an embolism.

CT angiograms have now largely replaced standard pulmonary arteriograms: the dye can be injected into a peripheral vein (such as the antecubital vein in the elbow) instead of passing a catheter into the pulmonary artery through the jugular, subclavian, or the femoral vein. A CT scan of the chest then accurately reveals the area of the embolic blood clot in the lungs.

PET Scans

PET scans (positron emission tomography scans) are scans obtained after the administration of a short-lived highly-energetic radioisotope to the patient. The radioisotope emits positrons which collide with electrons in the body tissues and cause the emission of paired gamma rays which go in opposite directions and are both detected by the scanner. The radioisotopes are often combined with glucose, which is utilized by parts of the brain undergoing the most activity during the scan. The scanner thus has a computerized algorithm similar to a CT scanner that creates an image of brain activity. These unstable radioisotopes must generally be created in a cyclotron in the hospital where the PET scan is being done, or near to the hospital.

PET scans therefore show areas of greatest brain activity in a given patient at a certain point in time -while working math problems, or playing Chopin on the piano, for example…or possibly during a seizure. These scans are often utilized in patients with brain cancer, as cancer is more biologically active than the surrounding tissues. Often PET scans are used in conjunction with CT scans or MRI's. PET scans show the activity, and the CT scans show the anatomy of the tissues.

SPECT Scans

SPECT scan stands for single photon emission computed tomography. Available in teaching hospitals only, it is quite similar to PET scans. It involves the injection of a radioisotope and scanning with a gamma camera to obtain very precise body images, also in the form of slices.

These scans are similar in that respect to CT scans. They show tissue activity very precisely, and are especially popular in scanning the brain to detect the areas of greatest activity. The radioisotopes used in this type of scan give off a single gamma ray (those in PET scans give off a double gamma ray).

SPECT scans are used to study brain activity in certain conditions. They are especially good for epilepsy. These scans are often used to study blood flow in diseased conditions. PET scans diffuse better in solid tissue, whereas SPECT scans light up the active blood flow in terms of which tissues are taking up the most nutrients. Both PET scans and SPECT scans can create 3-D images of the brain.

Functional MRI (fMRI) Scans

This is an MRI procedure that measures brain activity by detecting associated changes in blood flow. The primary form of fMRI uses the blood-oxygen-level-dependent (BOLD) contrast technique. This is a type of specialized brain and body scan used to map neural activity in the brain or spinal cord of humans or animals by imaging the change in blood flow (hemodynamic response) related to energy use by brain cells (at any given minute in time). fMRI has recently begun to dominate brain mapping research because it does not require people to undergo injections, to ingest substances, or be exposed to radioactive radiation markers. Furthermore, no cyclotron needs to be nearby.

The procedure is similar to MRI but it uses the change in magnetization between oxygen-rich and oxygen-poor blood as its basic measure. Thus it is incredibly sensitive. The resulting brain activation can be presented graphically by color-coding the strength of activation across the brain or the specific region studied. Oxygen use changes the magnetization of the scan which is given a color in the resulting images. The technique can localize brain activity to within millimeters and within a time frame of a few seconds.

The central idea behind fMRI technology is to capture functional changes in the brain caused by neuronal activity. Differences in magnetic properties between arterial (oxygen-rich) and venous (oxygen-poor) blood provides this link. Oxygen utilization, which this scan detects, results in electrical activity of the cell, as in thinking or transmitting information in the brain.

The attractions of fMRI have made it a popular tool for imaging normal brain function – especially for psychologists. Over the last decade it has provided new insight to the investigation of how memories are formed, language, pain responses, learning, and emotional responses.

Use in lie detection:

At least two companies have been set up to use fMRI in lie detection: No Lie MRI and the Cephos Corporation. These companies charge $5000 or more for one of their lie tests. Their working protocol depends on evidence such as that in a study by Joshua Greene at Harvard University suggesting the prefrontal cortex is more active in those contemplating lying, whereas people telling the truth use other parts of the brain. The prefrontal cortex is turned on when a person is thinking about his/her thinking, analyzing how to react to something someone else has said. We do this more when we're lying than we do when we are telling the truth and simply react to what we actually believe to be true. Our prefrontal cortex processes how we are going to pretend we are telling the truth…when we are not!

fMRI scans can be used when a person who is a suspect in a crime is shown the crime scene and then asked, "Have you seen this room before or not?" If the actual criminal is getting the scan, and he lies by responding, "No, I've never seen this room before!" his pre-frontal cortex will light up! If an innocent suspect is shown the scene (or pictures of the scene), and he is asked the same question, only the occipital cortex visual center will light up, suggesting that he will be telling the truth.

There is still a fair amount of controversy over whether these techniques are reliable enough to be used in a legal setting (similar to the controversy for years over the galvanic skin response lie detectors, which are now quite widely accepted by the courts). Some studies indicate that while there is an overall positive correlation, there is a great deal of variation between findings and, in some cases, considerable difficulty in replicating the findings.

A federal magistrate judge in Tennessee prohibited fMRI evidence to back up a defendant's claim of telling the truth, on the grounds that such scans do not yet measure up to the legal standard of scientific evidence. Most researchers agree the ability of fMRI scans to reliably dig out deception in the general population is still rather limited, but it is being carefully studied. My prediction is that it will get better and better… but will never be perfect.

Use in brain injuries:

fMRI scans of a brain-injured person can show how deep the coma is. Some scans have been taken on comatose patients, when the non-responding person was being spoken to. The fMRI scan has sometimes shown that the auditory responding center lights up, and sometimes even the verbal response center, although the person is locked into their coma and cannot move any muscles to respond verbally to what they are actually hearing! Such scans might also be used to determine if a deeply comatose person is actually brain dead or not.

fMRI scans have a futuristic quality to them. I am waiting for this kind of cutting-edge technology to be applied to the study of energy channels in the body. I do believe this will happen.

JULY 2013