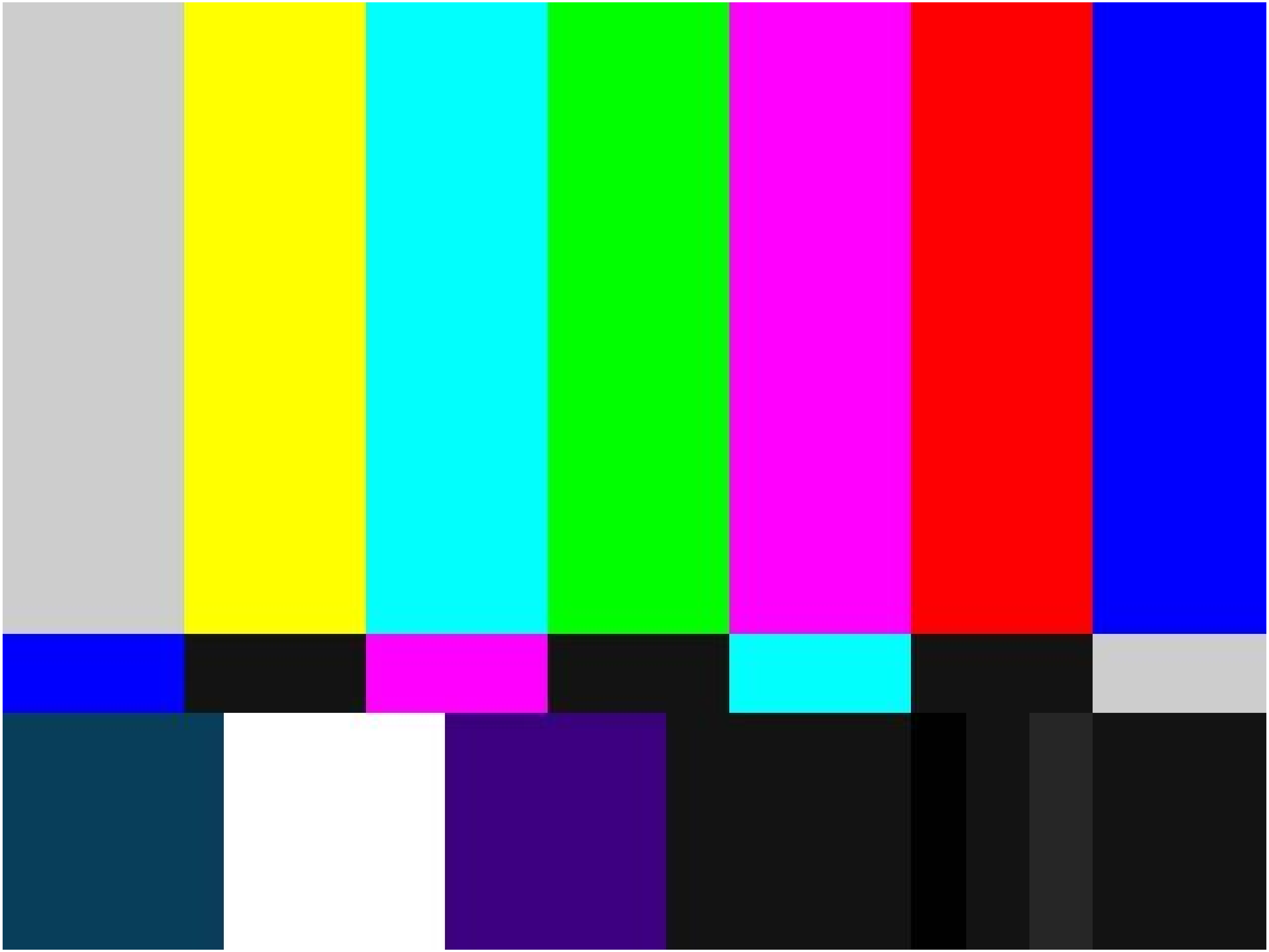

Medical Imaging (MRI)

By:
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MRI History

- July 3, 1977 - was the first MRI exam ever performed on a human being.
- It took almost five hours to produce one image.
- **Dr. Raymond Damadian**, a physician and scientist, along with colleagues **Dr. Larry Minkoff** and **Dr. Michael Goldsmith**,
  - labored tirelessly for seven long years to reach this point.
- Late 1982 to present - MRI can image in seconds what used to take hours.

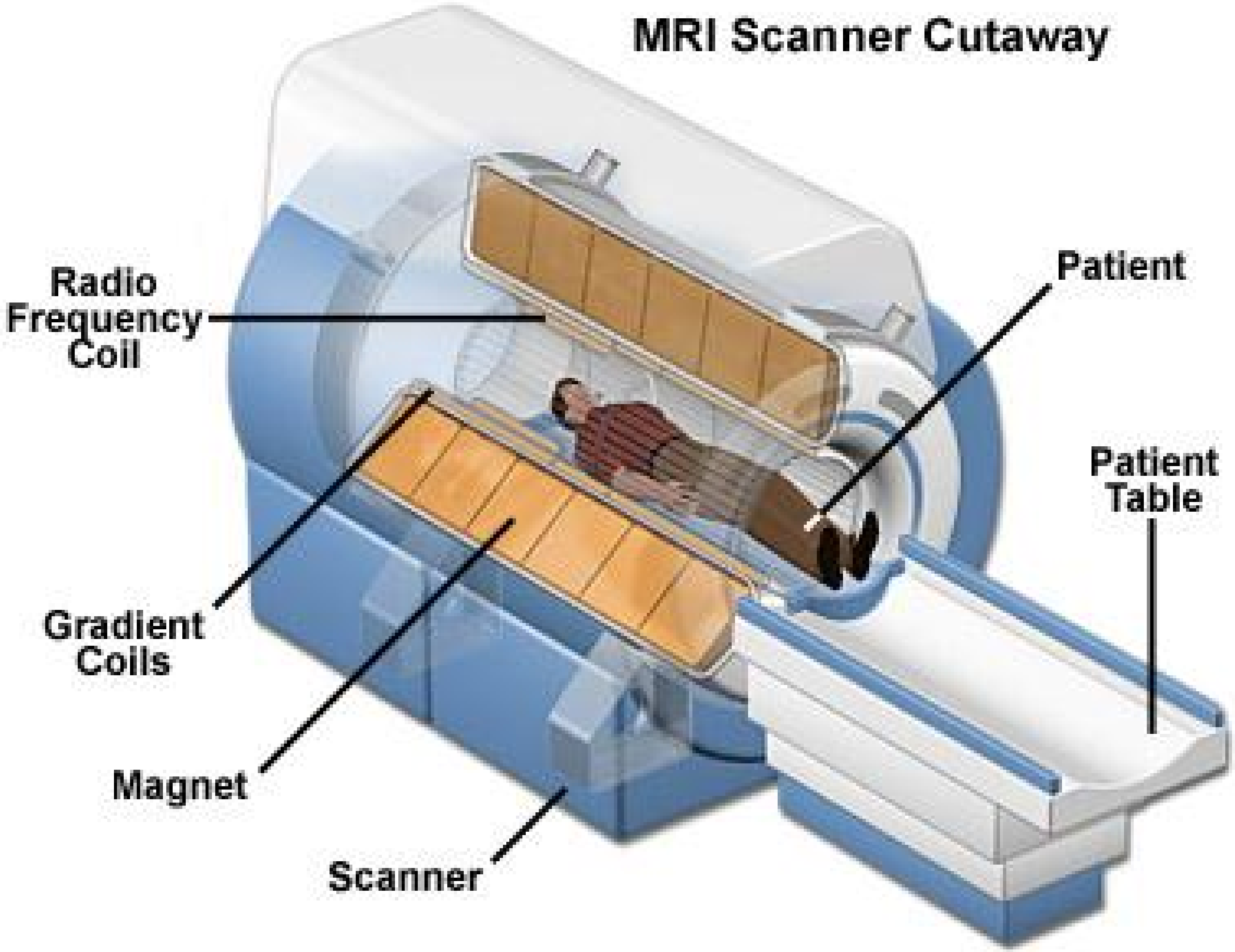
Magnetic resonance imaging (MRI)

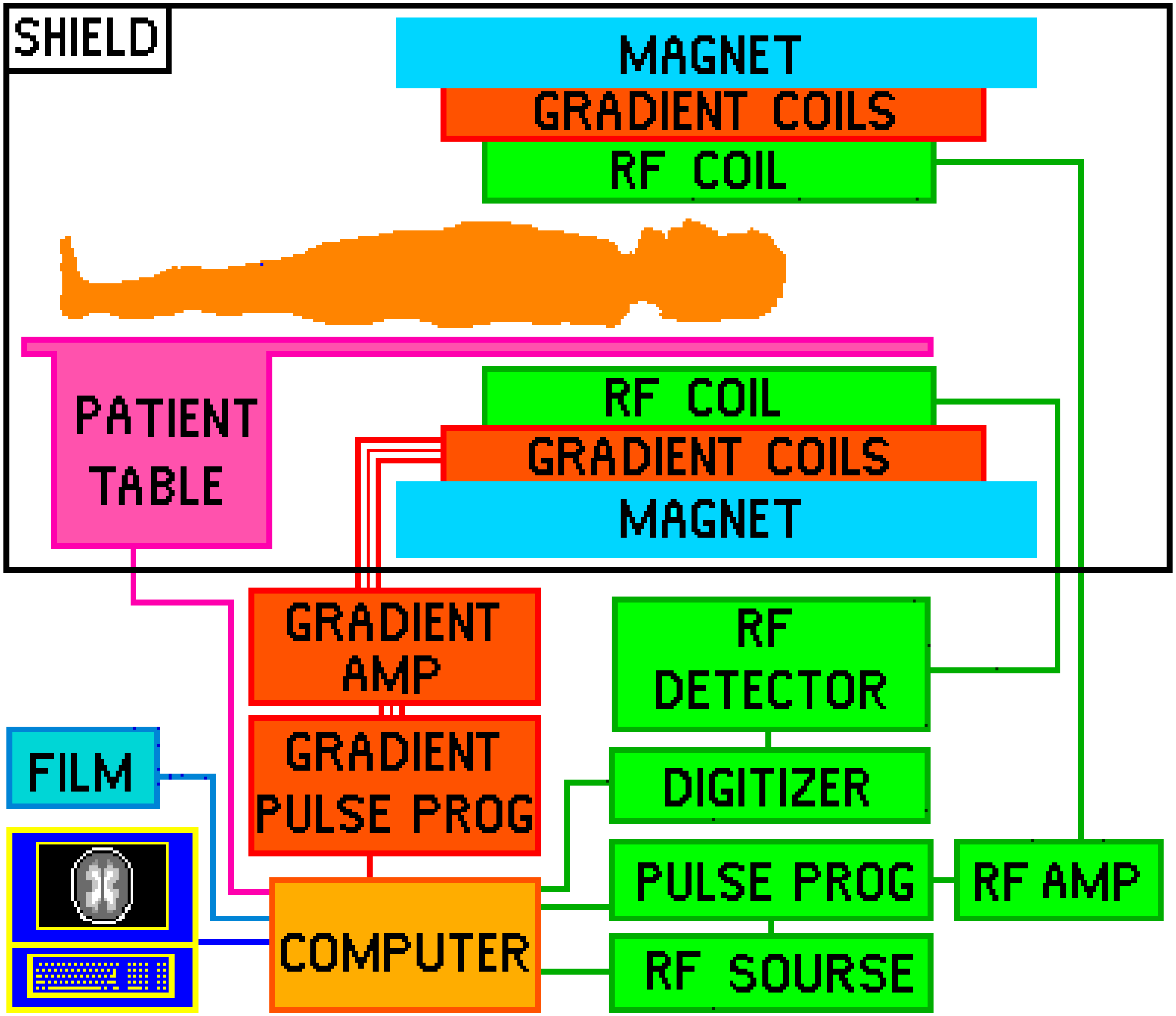
- is primarily used in medical imaging to visualize the structure and function of the body. It provides detailed images of the body in any plane.
- MR has much greater soft tissue contrast than Computed tomography (CT) making it especially useful in neurological, musculoskeletal, cardiovascular and oncolological diseases.

MRI Scan

- The basic design used in most is a giant **cube**. The cube in a typical system might be 7 feet tall by 7 feet wide by 10 feet long (2 m by 2 m by 3 m), although new models are rapidly shrinking.
- There is a **horizontal tube** running through the **magnet** from front to back. This tube is known as the **bore** of the magnet.


PHILIPS


MRI Scanner Cutaway
Radio Frequency Coil
Patient
Patient Table
Gradient Coils
Magnet
Scanner

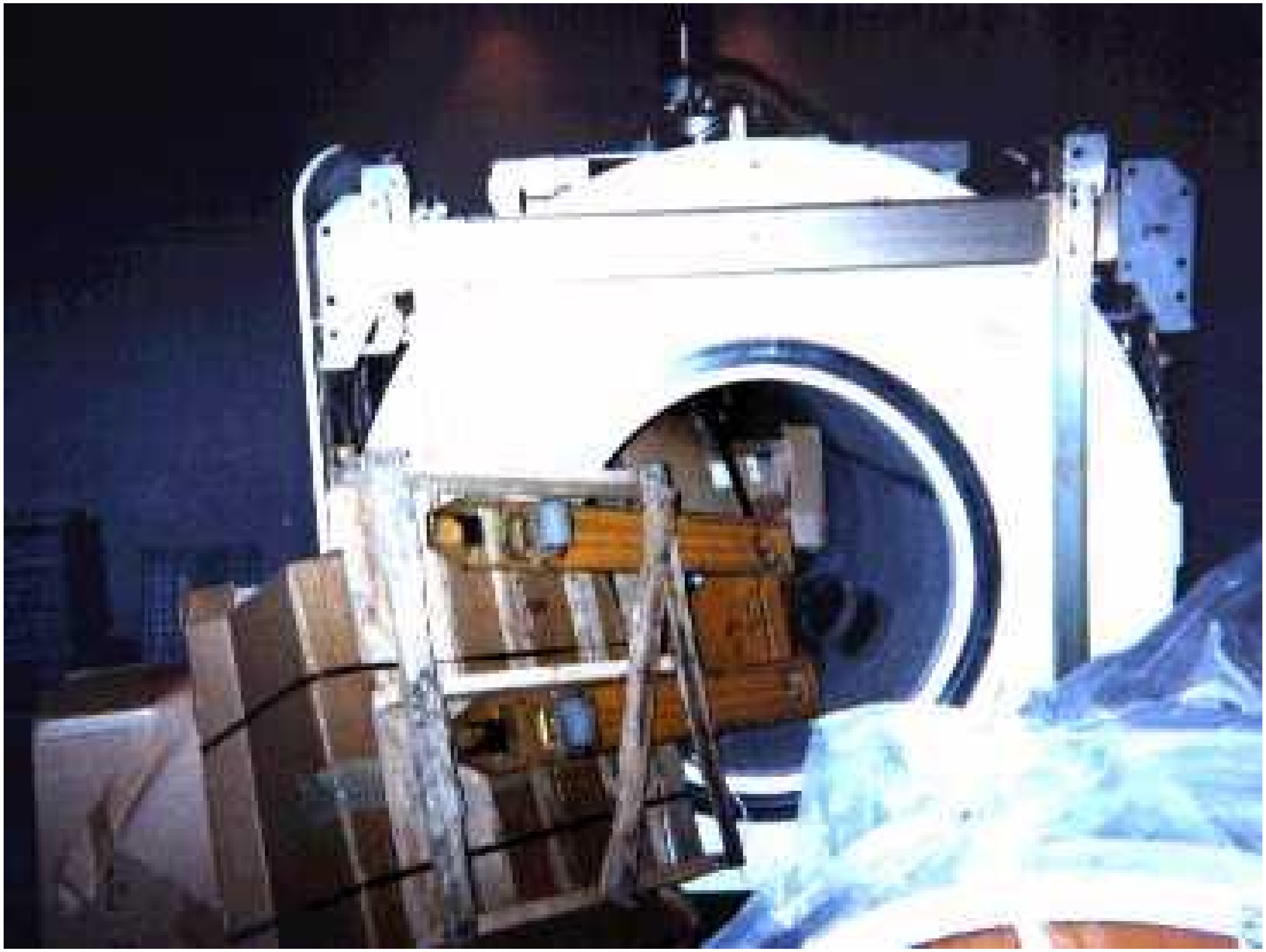

SHIELD
MAGNET
GRADIENT COILS
RF COIL
PATIENT
TABLE
RF COIL
GRADIENT COILS
MAGNET
GRADIENT
AMP
RF
DETECTOR
GRADIENT
PULSE PROG
FILM
DIGITIZER
PULSE PROG
RF AMP
COMPUTER
RF SOURSE

Magnetic Resonance

- The biggest and most important component in an MRI system is the **magnet**.
- The magnet in an MRI system is rated using a unit of measure known as a **tesla**.
- Another unit of measure commonly used with magnets is the **gauss** (1 tesla = 10,000 gauss).
- The magnets in use today in MRI are in the 0.5-tesla to 2.0-tesla range, or 5,000 to 20,000 gauss.
- Magnetic fields greater than **2 tesla** have not been approved for use in medical imaging, though much more powerful magnets -- up to 60 tesla -- are used in research.

Magnetic Resonance

- The MRI suite can be a very dangerous place if strict precautions are not observed.
- **Metal objects** can become dangerous projectiles if they are taken into the scan room.
- The **magnetic force** exerted on an object increases **exponentially** as it nears the magnet.



MRI Safety

- Prior to allowing a patient or support staff member into the scan room, he or she is thoroughly screened for metal objects. (External metal Objects)
- Internal Metal Objects is also hazardous.
  - Metallic fragments in the eye
  - Pacemakers
  - Aneurysm clips (brain)
  - Dental implants
  - Orthopedic implants

MRI Safety

- There are no known biological hazards to humans from being exposed to magnetic fields of the strength used in medical imaging today.
- Most facilities prefer not to image **pregnant women**. This is due to the fact that there has not been much research done in the area of biological effects on a developing fetus. The first trimester in a pregnancy is the most critical because that is the time of the most rapid cellular reproduction and division.

MRI Magnet

- There are three basic types of magnets used in MRI systems:
  1. **Resistive magnets** consist of many windings or coils of wire wrapped around a cylinder or bore through which an electric current is passed. This causes a magnetic field to be generated. If the electricity is turned off, the magnetic field dies out. These magnets are lower in cost to construct than a superconducting magnet (see below), but require huge amounts of electricity (up to 50 kilowatts) to operate because of the natural resistance in the wire. To operate this type of magnet above about the 0.3-tesla level would be prohibitively expensive.

MRI Magnet

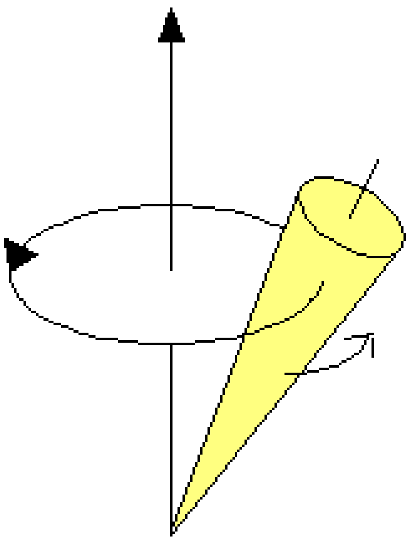
- There are three basic types of magnets used in MRI systems:
  2. A **permanent magnet** is just that -- permanent. Its magnetic field is always there and always on full strength, so it costs nothing to maintain the field. The major drawback is that these magnets are extremely heavy: They weigh many, many tons at the 0.4-tesla level. A stronger field would require a magnet so heavy it would be difficult to construct. Permanent magnets are getting smaller, but are still limited to low field strengths.

MRI Magnet

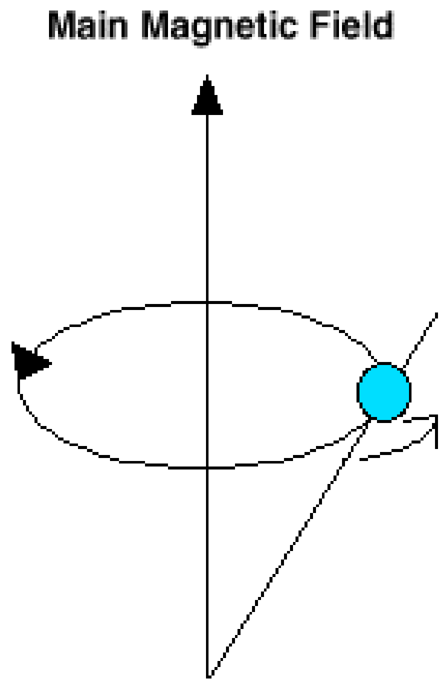
- There are three basic types of magnets used in MRI systems:
  3. **Superconducting magnets** are by far the most commonly used. A superconducting magnet is somewhat similar to a resistive magnet -- coils or windings of wire through which a current of electricity is passed create the magnetic field. The important difference is that the wire is continually bathed in liquid helium at 452.4 degrees below zero. his almost unimaginable cold causes the resistance in the wire to drop to zero, reducing the electrical requirement for the system dramatically and making it much more economical to operate. Superconductive systems are still very expensive, but they can easily generate 0.5-tesla to 2.0-tesla fields, allowing for much higher-quality imaging.

How MRI Works: Atoms

- The human body is made up of untold billions of atoms, the fundamental building blocks of all matter. The nucleus of an atom spins, or **precesses**, on an axis.



A top that is spinning slightly off the vertical axis is precessing about the vertical axis.



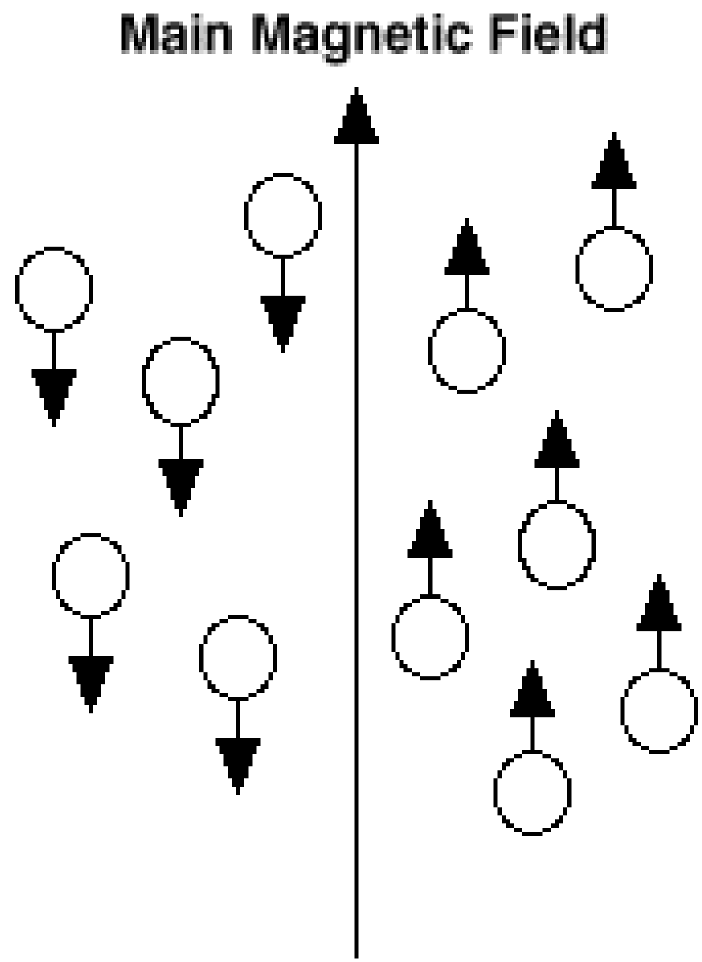
A hydrogen atom precesses about a magnetic field.

How MRI Works: Atoms

- Imagine billions of nuclei all randomly spinning or precessing in every direction.
- There are many different types of atoms in the body, but for the purposes of MRI, only concerned with the **hydrogen atom**.
- It is an ideal atom for MRI because its nucleus has a **single proton** and a large **magnetic moment**.
- The large magnetic moment means that, when placed in a magnetic field, the hydrogen atom has a strong tendency to line up with the direction of the magnetic field.

How MRI Works: Atoms

All of the hydrogen protons will align with the magnetic field in one direction or the other. The vast majority cancel each other out, but, as shown here, in any sample there is one or two "extra" protons.



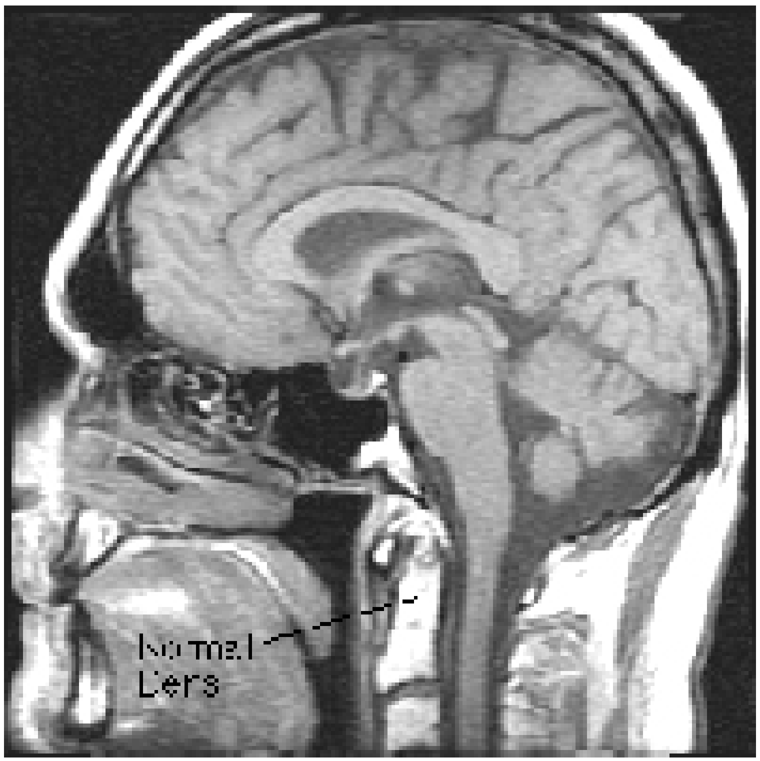
MRI Machine

- The MRI machine applies an RF (radio frequency) pulse that is specific only to hydrogen.
- The system directs the pulse toward the area of the body we want to examine.
- The pulse causes the protons in that area to **absorb the energy** required to make them spin, or **precess**, in a different direction. This is the "**resonance**" part of MRI.
- The RF pulse forces them (only the one or two extra unmatched protons per million) to spin at a particular frequency, in a particular direction.
- The specific frequency of resonance is called the **Larmour frequency** and is calculated based on the particular tissue being imaged and the strength of the main magnetic field.

MRI Images

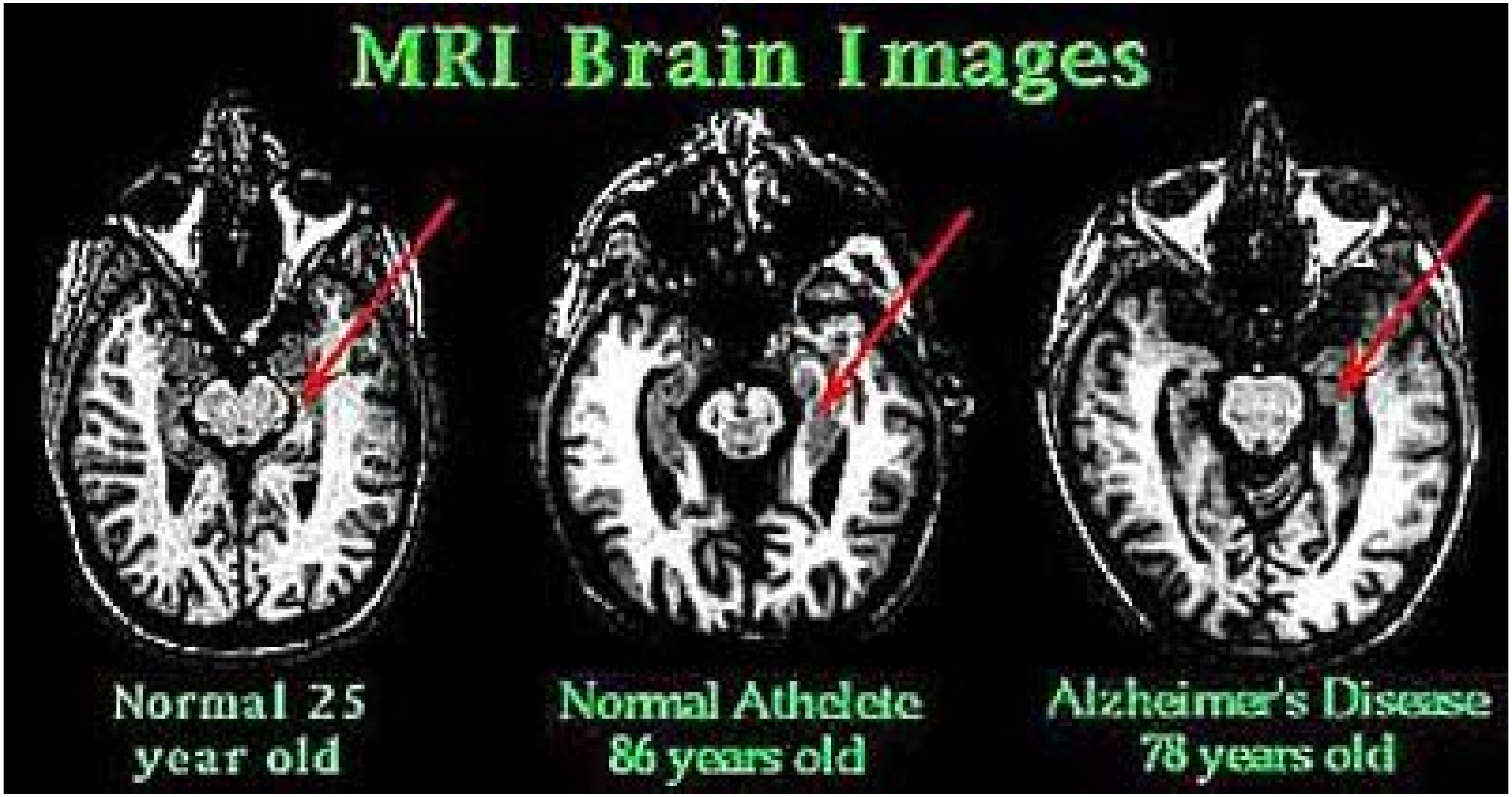
This MRI scan shows the upper torso in side view so that the bones of the spine are evident.

MRI Images

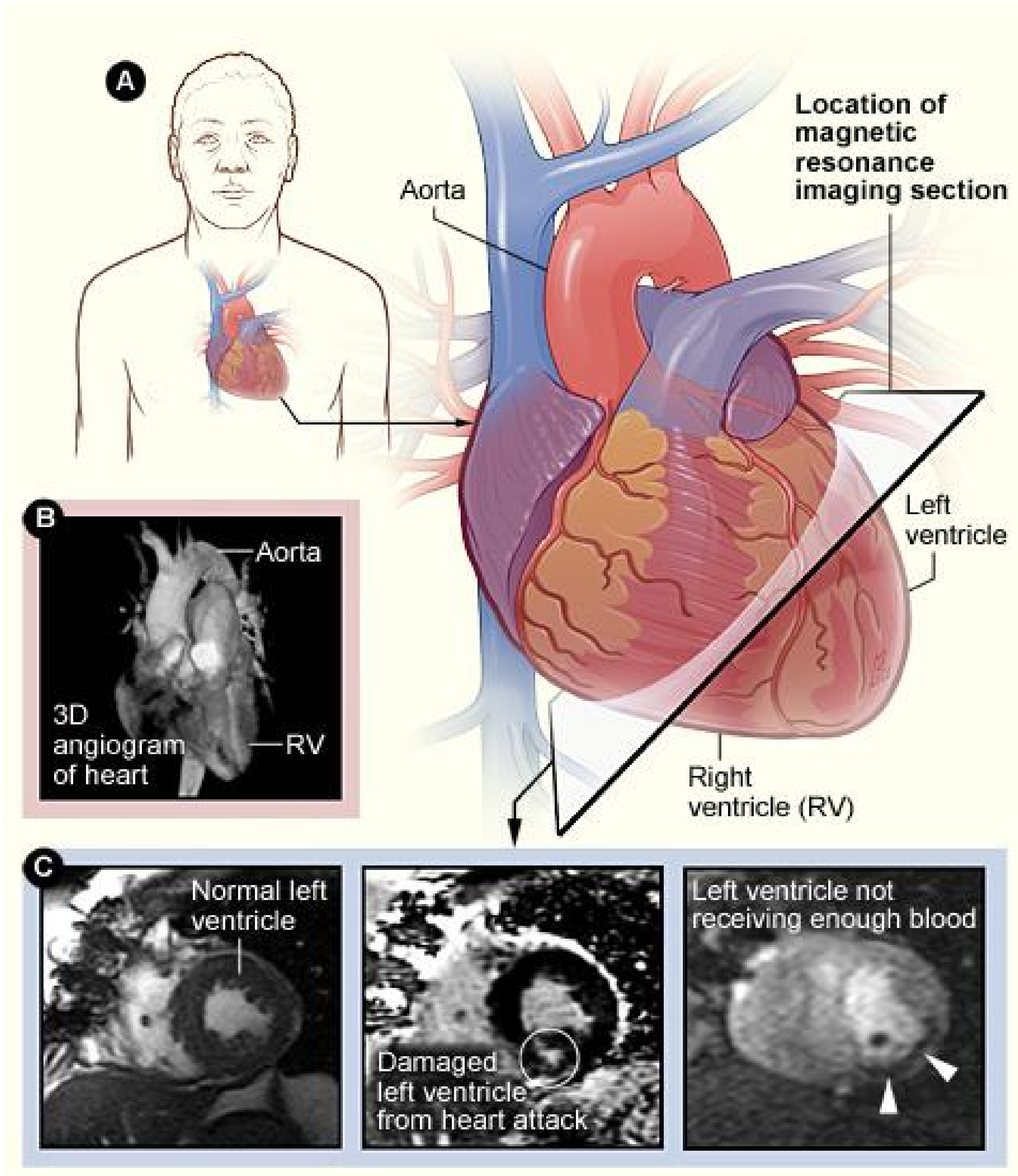


This image shows the tumor growth in a female's brain, sliced here in lateral view.

MRI Images



This image set is comparing a young individual (left) with an athletic male in his 80's (center) and with a person of similar age having Alzheimer's Disease (right), all imaged at the same level.



A
Location of magnetic resonance imaging section
Aorta
Left ventricle
Right ventricle (RV)
B
Aorta
3D angiogram of heart
RV
C
Normal left ventricle
Damaged left ventricle from heart attack
Left ventricle not receiving enough blood

MRI Advantages

- MRI is ideal for:
  - Diagnosing **multiple sclerosis** (MS)
  - Diagnosing **tumors** of the pituitary gland and brain
  - Diagnosing **infections** in the brain, spine or joints
  - Visualizing **torn ligaments** in the wrist, knee and ankle
  - Visualizing **shoulder injuries**
  - Diagnosing **tendonitis**
  - Evaluating **masses** in the soft tissues of the body
  - Evaluating **bone tumors**, **cysts** and **bulging or herniated discs** in the spine
  - Diagnosing **strokes** in their earliest stages

MRI Disadvantages

- It does have drawbacks.
  - There are many people who cannot safely be scanned with MRI (for example, because they have **pacemakers**), and also people who are **too big** to be scanned.
  - There are many **claustrophobic** people in the world, and being in an MRI machine can be a very disconcerting experience for them.
  - The machine makes a tremendous amount of **noise** during a scan. The noise sounds like a continual, rapid hammering. Patients are given earplugs or stereo headphones to muffle the noise (in most MRI centers you can even bring your own cassette or CD to listen to). The noise is due to the rising electrical current in the wires of the gradient magnets being opposed by the main magnetic field. The stronger the main field, the louder the gradient noise.

MRI Disadvantages

- It does have drawbacks.
  - MRI scans require patients to **hold very still** for extended periods of time. MRI exams can range in length from 20 minutes to 90 minutes or more. Even very slight movement of the part being scanned can cause very distorted images that will have to be repeated.
  - Orthopedic hardware (screws, plates, artificial joints) in the area of a scan can cause severe **artifacts** (distortions) on the images. The hardware causes a significant alteration in the main magnetic field. Remember, a uniform field is critical to good imaging.
  - MRI systems are very, very **expensive** to purchase, and therefore the exams are also very expensive.

CT vs. MRI

- A computed tomography (CT) scanner uses X-rays, a type of ionizing radiation, to acquire its images, making it a good tool for examining tissue composed of elements of a relatively higher atomic number than the tissue surrounding them, such as bone and calcifications (calcium based) within the body (carbon based flesh), or of structures (vessels, bowel).
- MRI, on the other hand, uses non-ionizing radio frequency (RF) signals to acquire its images and is best suited for non-calcified tissue.

CT vs. MRI

- CT may be enhanced by use of contrast agents containing elements of a higher atomic number than the surrounding flesh such as iodine or barium.
- Contrast agents for MRI are those which have paramagnetic properties.
- Both CT and MRI scanners can generate multiple two-dimensional cross-sections (slices) of tissue and three-dimensional reconstructions.

CT vs. MRI

- MRI is also best suited for cases when a patient is to undergo the exam several times successively in the short term, because, unlike CT, it does not expose the patient to the hazards of ionizing radiation.

Future of MRI

- The future of MRI seems limited only by our imagination. This technology is still in its infancy, comparatively speaking. It has been in widespread use for less than 20 years (compared with over 100 years for X-rays).
- Very **small scanners** for imaging specific body parts are being developed. For instance, a scanner that you simply place your arm, knee or foot in are currently in use in some areas. Our ability to visualize the arterial and venous system is improving all the time. Functional **brain mapping** (scanning a person's brain while he or she is performing a certain physical task such as squeezing a ball, or looking at a particular type of picture) is helping researchers better understand how the brain works. Research is under way in a few institutions to image the ventilation dynamics of the lungs through the use of hyperpolarized helium-3 gas. The development of new, improved ways to image strokes in their earliest stages is ongoing.