KREP

2025

KARNATAKA RADIOLOGY EDUCATION PROGRAM X

MRI PHYSICS

It is a non-invasive imaging technique that uses radio waves and strong magnets to create detailed images of inside the body.

MRI uses a powerful magnetic field, radio frequency pulses and a computer to produce detailed pictures of organs, soft tissues, bone and virtually all other internal body structures.

THE MRI MACHINE   MRI OF HUMAN BRAIN

Basic steps of MRI

1.Patient is placed in a magnet.

2.All randomly moving protons in the patient's body align and process along the external magnetic field.

3.RF pulse is sent - precessing protons pick up energy from RF pulse to go to higher energy level and process in phase with each other. This results in reduction in longitudinal magnetization and formation of transverse magnetisation in x-y plane.

4.MR signal is received - The transverse magnetisation vector precess in transverse plane and generates current. This current is received as signal by the RF coil.

5.Image formation- MR signal received by the coil is transformed into image by Fourier transformation by computer.

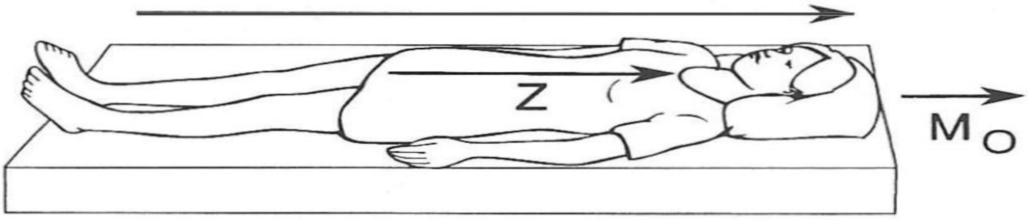


Figure 24–1 A patient in a 1-tesla magnetic field that is aligned along the Z axis. M_0 = longitudinal magnetization at equilibrium

Physics of MRI

Human body is made of cells, cells are made of various atoms, and all atoms contain protons in their nucleus.

- **Protons carry positive charge and possess spin.**
- **We know, moving charge is electric current, and electric current induces magnetic field.**
- **Thus, proton has its own magnetic field, and act as tiny bar magnets**

Patient is placed inside the magnet

When protons are placed in an external magnetic field, they align themselves with the field, similar to how a compass needle aligns with Earth's magnetic field.

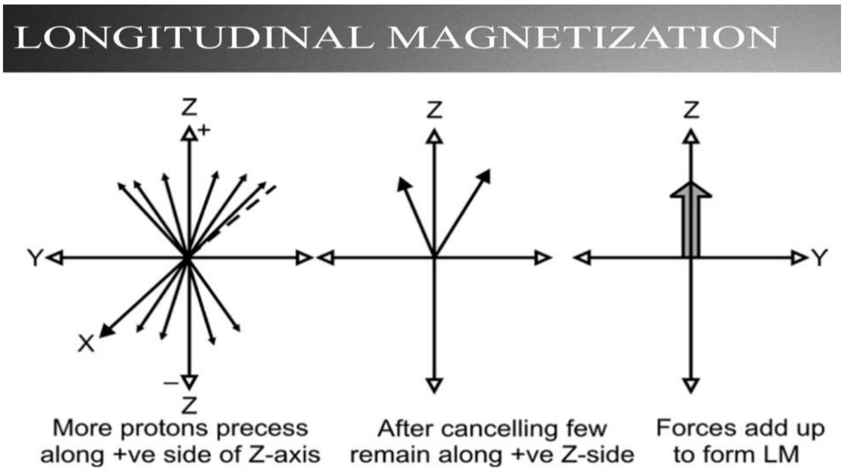
- **Protons can align in two ways: either parallel or antiparallel to the magnetic field.**
- **These two alignments have different energy levels. Protons naturally prefer the alignment that uses less energy.**

Longitudinal magnetization

Protons pointing in opposite directions cancel out each other's magnetic effects.

- **Since more protons align parallel to the external magnetic field, there is an overall magnetic effect in the same direction as the field.**

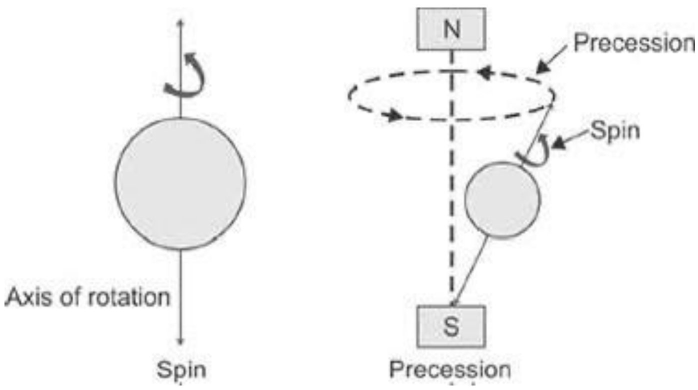
- **In a strong external magnetic field, a new magnetic vector is created in the patient, essentially turning them into a magnet.**
- **This new magnetic vector aligns with the external magnetic field and is called longitudinal magnetization.**



PROTON PRECESSION

In an external magnetic field, protons exhibit a movement called precession, which is similar to the wobbling motion of a spinning top just before it stops.

- **Understanding how fast protons precess is important. The number of precessions per second is called the precession frequency.**
- **The precession frequency depends on the strength of the magnetic field in which the protons are placed.**
- **This frequency can be calculated using the Larmor Equation (Ш0 = γBo).**



A RADIO WAVE IS SENT TO THE PATIENT

The purpose of the RF pulse is to disturb the protons that are precessing calmly in alignment with the external magnetic field.

- **To do this, we need an RF pulse that can transfer energy to the protons. This requires the RF pulse to have the same frequency as the precessing protons.**
- **When the RF pulse and protons match in frequency, the protons absorb energy from the radio wave. This phenomenon is called resonance, which is where the term "resonance" in magnetic resonance originates.**
- **The frequency of the required RF pulse can be calculated using the Larmor Equation.**

EFFECT OF RF PULSE

Some protons absorb energy and transition from a lower energy level to a higher one. In other words, some protons that were previously aligned with the magnetic field (parallel) now align against it (antiparallel).

- **This shift reduces the longitudinal magnetization because fewer protons remain aligned with the external magnetic field.**

The RF pulse causes the protons to precess in sync, meaning they all point in the same direction at the same time. As a result, their magnetic forces combine in that direction.

- **This creates a magnetic vector pointing to the side where the protons are precessing, in the transverse direction (along the X-Y plane).**
- **This phenomenon is known as transversal magnetization**

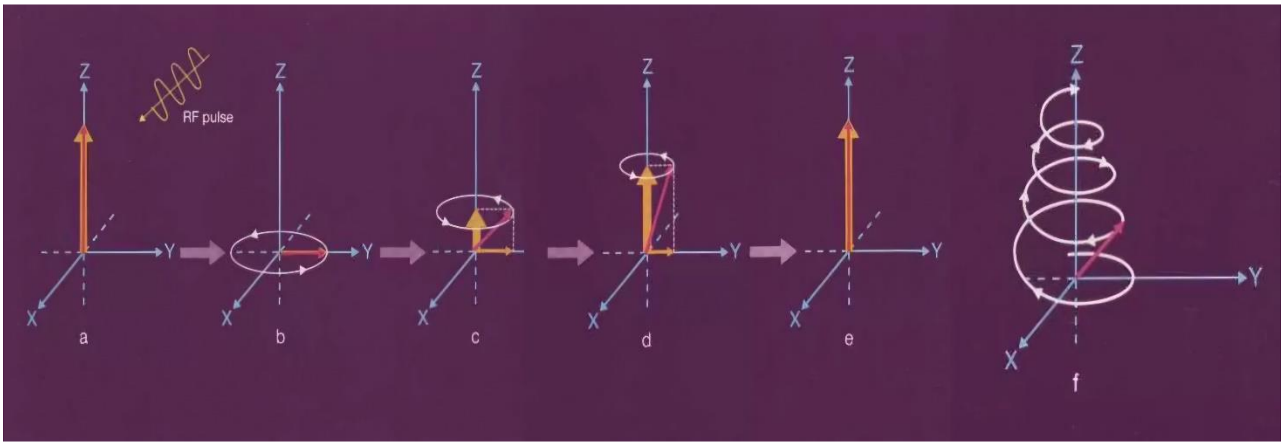
TRANSVERSE MAGNETIZATION

Transverse magnetization is the combined magnetic effect of protons precessing at the same frequency. These protons are constantly exposed to static or slowly changing local magnetic fields.

- When the RF pulse is turned off, the protons lose their synchronized motion (dephase), causing the transverse magnetization to gradually decrease. This process is called transverse relaxation.
- Dephasing is influenced by fluctuating local magnetic fields created by nearby protons (spins), which is why transverse relaxation is also known as spin-spin relaxation.
- The time it takes for transverse magnetization to decay to about 37% of its original value is called the transverse relaxation time, or T2.

THE RADIO WAVE IS TURNED OFF

- Before the RF pulse, only longitudinal magnetization was present.
- After a 90° RF pulse, all the magnetization shifts to the transverse plane, creating transversal magnetization, which begins spinning.
- Once the RF pulse is removed, the transversal magnetization gradually decreases, while the longitudinal magnetization slowly recovers. This recovery occurs in a spiral motion over time.



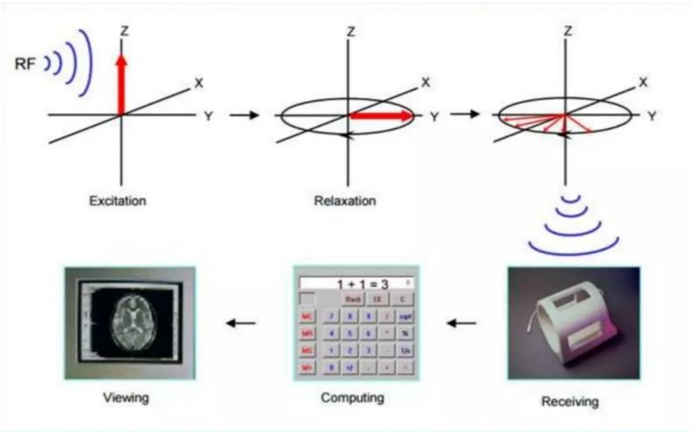
OBTAINING MRI SIGNAL FROM THE PATIENT

When an antenna is placed near the tissue, the spiraling motion of the magnetic vector (from the transverse to the longitudinal direction) induces an electric current in the antenna.

- As the magnetic vector spirals and gradually moves away from the antenna, the amplitude of the induced current decreases over time.
- This gradual reduction in signal is called the FID signal (Free Induction Decay).

COMPUTING AND DISPLAY

The received signal is processed by a computer, and within a quarter of a second, an image is generated and displayed on the screen.



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REF : Christensen's Physics of Diagnostic Radiology, Radiopedia.