Radiology

Lec. 18 **Magnetic Resonance Imaging (MRI)** **د. اريج**

Magnetic Resonance Imaging (MRI), nuclear magnetic resonance imaging (NMRI), or magnetic resonance tomography (MRT) is one of the most powerful diagnostic tools, highly sensitive and specific imaging modality that is being used in radiology and diagnostic science. Magnetic resonance imaging is used to visualize internal structures of the body in detail. Unlike conventional x-ray examinations and computed tomography (CT) scans, MRI does not depend on ionizing radiation. Instead, it depends on the magnet and radio frequency waves (RF). MRI uses the property of nuclear magnetic resonance (NMR) to image nuclei of atoms inside the body.

Types of MRI

1. Closed MRI
2. Open MRI
3. Extremity MRI
4. Dynamic MRI

Mechanism of MRI

To make an MR image, the patient is first placed inside a large magnet. This magnetic field causes the nuclei of many atoms in the body especially hydrogen, to align with the magnetic field. Then RF pulse has been emitted, causing some hydrogen nuclei to absorb energy and resonate. When the RF pulse is turned off, the stored energy is released from the body and the signals detected by coils in the scanner.

The magnetic field in MRI scanner is provided by external powerful permanent magnet with strength range from (0.1- 4 Tesla), the 1.5 Tesla is the most commonly used and it's about 30000 times the strength of the earth's magnetic field.

- As a strong magnet is used, all metallic devices MUST be removed before entering the MRI room. This includes clothes with metal zips and jewelry.

Magnetic Resonance Signal

The MR signal received by a coil after RF pulse turning off, the magnitude of this signal is proportional to the overall concentration of hydrogen nuclei (proton density) in the tissue. The strength of the signal also depends on the degree to which hydrogen is bound within a molecule. **Tightly bound** hydrogen atoms as those present in bone, don't align themselves with the external magnetic field and produce only weak signal. While **loosely bound** or mobile hydrogen atoms as those present in soft tissues and liquids, react to the RF pulse and produce a detectible strong signal. The higher concentration of loosely bound hydrogen atoms, the stronger magnetization, the more intense recovered signal, and the brighter corresponding part of MR image.

T1 and T2 relaxation time

T1 relaxation time represents the time required for 63% of the net magnetization to return to equilibrium, so it reflects the ability of hydrogen atoms to transfer their excess energy to surrounding molecules.

T2 relaxation time is the time constant that describe the exponential rate of loss of transverse magnetization.

Tissue contrast

It depends on proton density, T1 and T2 times of the tissue being imaged.

T1- Weighted image: are most commonly used to demonstrate anatomy of the part being imaged depending on the differences in T1 values of tissues. Tissues with short T1 times, such as fat, appear bright. While tissue with long T1 times, such as CSF (water or fluid), appear dark.

T2- Weighted image: are most commonly used for identifying pathology because pathological tissue usually contain more water than surrounding tissues due to inflammation, depending on the differences in T2 values of tissues. Tissues with long T2 times, such as CSF or TMJ fluid, appear bright. While tissue with short T2 times, such as fat, appear dark.

MRI contrast agents

MRI provides good contrast between the different soft tissues of the body, which makes it especially useful in imaging the brain, muscles, the heart, and cancers compared with other medical imaging techniques such as computed

tomography (CT) or X-rays. Unlike CT scans or traditional X-rays, MRI does not use ionizing radiation.

contrast agents most commonly Gadolinium, may be injected intravenously to enhance the appearance of blood vessels, tumors or inflammation. Contrast agents may also be directly injected into a joint in the case of arthrograms (MRI images of joints).

Gadolinium is not imaged itself, but it shortens the T1 relaxation times of the enhancing tissues making them appear brighter.

MRI versus CT

1. A computed tomography (CT) scanner uses X-rays (ionizing radiation) to acquire images, making it a good tool for examining tissue composed of elements of a 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 soft tissue (although MRI can also be used to acquire images of bones & teeth) .

2. A contrast in CT images is generated purely by X-ray attenuation, while a variety of properties may be used to generate contrast in MR images. Contrast agents for CT contain elements of a high atomic number, relative to tissue, such as iodine or barium, while contrast agents for MRI have paramagnetic properties, such as gadolinium and manganese, used to alter tissue relaxation times.

3. For purposes of tumor detection and identification in the brain, MRI is generally superior. However, in the case of solid tumors of the abdomen and chest, CT is often preferred as it suffers less from motion artifacts. Furthermore, CT usually is more widely available, faster, and less expensive. However, CT has the disadvantage of exposing the patient to harmful ionizing radiation

Advantages of MRI

1. It offers best contrast resolution of soft tissues
2. No ionizing radiation is involved with MRI
3. Direct multi planar imaging is possible without patient re-orientation

Disadvantages of MRI

1. Long imaging time sometimes reaching 30 min.
2. Hazard associated with metal objects (ferromagnetic metals) present in patient's body such as cardiac pacemaker, cerebral aneurysm clips, shrapnel, vagus nerve stimulators, insulin pumps, cochlear implants. The strong magnetic field may harm the patient by moving this metal object, cause excessive heating, or induce strong electrical currents.
3. Some patients have claustrophobia and discomfort when positioned in MRI machine as a result of narrow area or acoustic noise , this can be managed by using open MRI, chemical sedation , general anesthesia, or listening to music on headphones.
4. Gadolinium contrast agent is known to cross the placenta and enter the fetal blood stream, so it is recommended that their use should be avoided in pregnancy.
5. High imaging cost.

- Gold and stainless steel are considered to be ferromagnetic, whereas titanium, nickel, amalgam restorations and silver palladium are not.

- There is medical evidence that a tattoo can cause a reaction during magnetic resonance imaging . The tattoo inks expected to cause a reaction are those containing iron oxide (some black, brown, red, flesh, yellow, orange). Not all dyes of these colors contain iron oxide. Also, some dyes of other colors may contain lesser quantities of magnetic metal. Magnetic metals can convert the radio-frequency pulses of an MRI machine into electricity. The burning sensation that would be felt at the site of the tattoo may be a result of electricity running through the tattoo or from the 'pull' exerted on the magnetic material in the tattoo.

Application of MRI

Because of its excellent soft tissue contrast resolution, MRI is used in evaluating soft tissue conditions such as:

1. Position and integrity of the disk in the TMJ.
2. Evaluating soft tissue diseases especially neoplasia of tongue, cheek, neck and salivary gland.
3. Determining malignant involvement of lymph nodes.
4. MR angiography used to visualize the blood flowing in vessels for arteries imaging to diagnose occlusion, aneurysm or malformation.

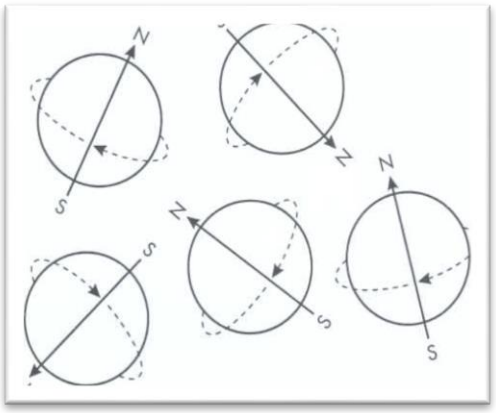

Fig 1: randomly oriented atoms

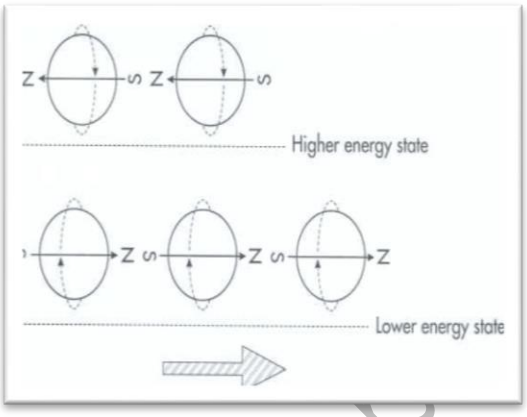

fig 2: atoms with applied magnetic field

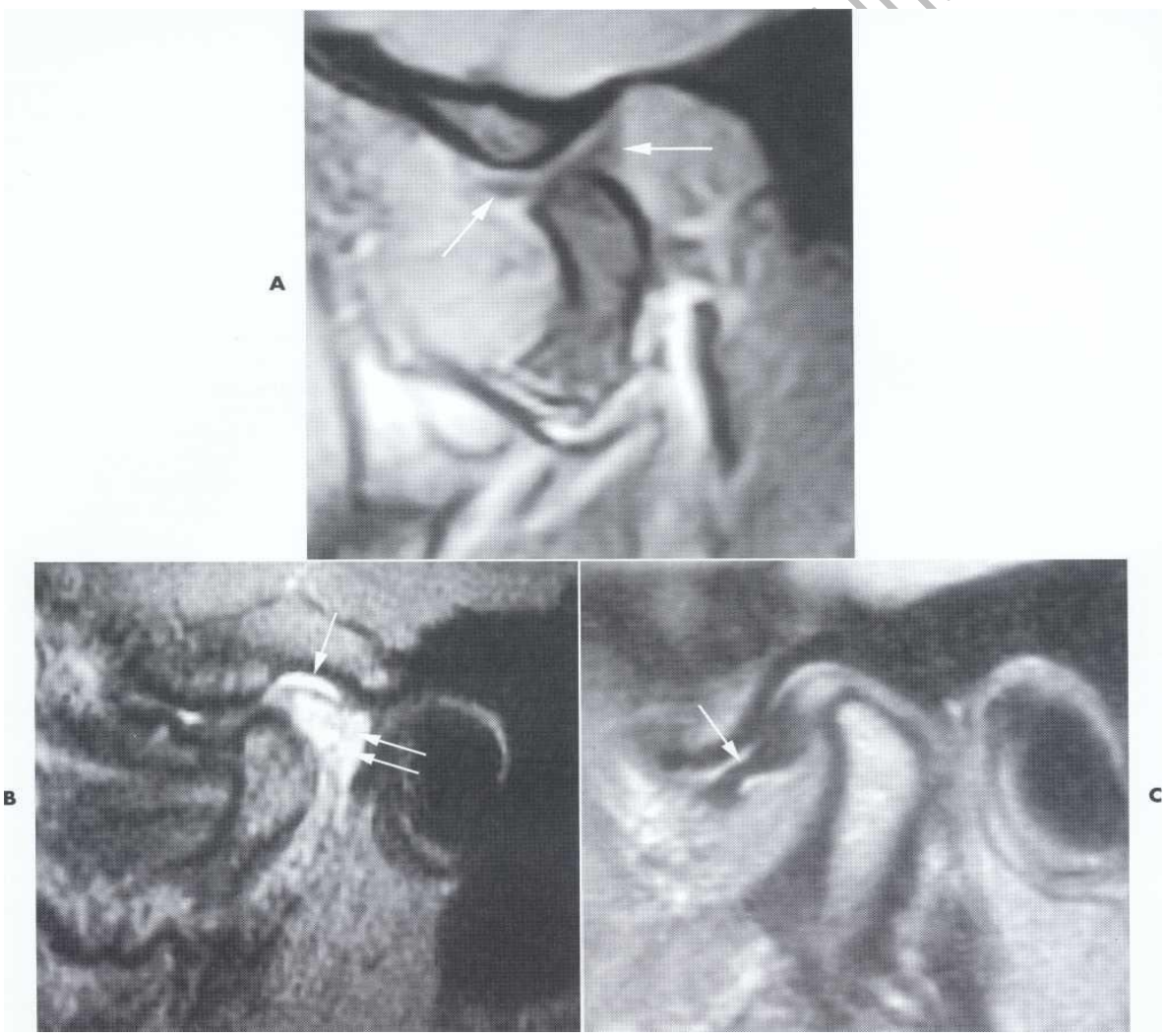

FIG. 3 A, T1 -weighted MR image of the TMJ.. B, T2-weighted MR image *C,* the disk is anteriorly displaced *(arrow),* with the posterior band in the 9 o'clock position relative to the condylar head.