Al-Mustaqbal University
College of Health and Medical Technologies
Radiological Techniques Department

Magnetic Resonance Imaging

First Semester

Lecture 2 :

- **Tissue characterization**
- **Pathological changes and effect of relation time**

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Tissue characterization:

Introduction

Magnetic resonance imaging is a diagnostic modality providing **cross-sectional imaging of the entire body in any plane with no radiation risk to the patient.** There are no known adverse effects.

Role Of MRI In Diseases

MRI has unique properties. **It is a complex yet interesting imaging technique utilized for the diagnosis of various diseases in all parts of the body.** MRI is very sensitive to certain pathologies, demonstrating disorders not shown on other imaging modalities, i.e. CT. **The rapid advances in MRI have resulted in many new pulse sequences providing details about tissue characterization.**

Production of Image

When the patient is placed in the scanner, **the applied external magnetic field (EMF) induces a net nuclear magnetization (NNM) in the longitudinal axis of the patient. This NNM is rotated through 90 degrees by the RF pulse.** When the RF pulse is discontinued, relaxation back to the original state occurs, i.e. **recovery of the magnetization in the longitudinal plane and**

decay of magnetization in the transverse plane. The recovery of longitudinal magnetization is known as spin lattice or T1 recovery. The decay of transverse magnetization is known as spin spin relaxation or T2 decay. T1 is determined by how quickly the nuclei can transfer energy to their surrounding environment (lattice) and return to a lower energy state. **T2 is determined** by how quickly the nuclei can exchange energy with neighboring nuclei to produce random distribution of the precessing nuclei about the magnetic field.

The sensitivity of MRI to certain substances, i.e. water and iron compounds, is of particular importance in clinical imaging. **For example, the high sensitivity of MRI to tissue water allows the effective demonstration of brain edema.** All types of edema namely **vasogenic, cytotoxic and interstitial**, result in altered signals and are best seen on T2 weighted images as a bright signal. The marked differences in the relaxation times of water and brain tissue enable the differentiation of tissues. For example, smaller structures such as cranial nerves that are bathed in cerebrospinal fluid (CSF) are well demonstrated on MRI. MRI is superior in the demonstration of tumors and other abnormalities of nerves, i.e. acoustic neuromas and lesions involving the optic chiasma.

The sensitivity of MRI to **paramagnetic substances** such as iron is of great clinical importance, as lesions of increased iron in pallideus, substantia nigra, red nucleus and dentate nucleus demonstrate a low signal on T2 weighted images. MRI is sensitive for the detection of cerebral ischemia, plus has the advantage of evaluating subacute and chronic trauma cases.

MRI Image

The image represents a display of the MR signal. The signal intensity depends on both the **tissue and equipment (operator) parameters**. It is important to understand that the gray scale on a MR image is not readily predictable and can be dramatically altered by machine-dependent parameters such as choice of pulse sequence, time between pulses (TE), repetition time (TR), inversion time (TI) etc. There are four main tissue MR parameters contributing to the signal intensity of an image: i) proton density, ii) T1, iii) T2 and iv) blood flow.

The MR image depends on the following four main factors;

- T1 relaxation time
- T2 decay time
- Proton density
- Blood flow.

Proton density, T1W and T2W

MR imaging is related to the density of mobile protons. Proton density is represented by the symbol (PD). The PD image is obtained using a spin echo sequence with long TR and short TE or a gradient echo sequence with a low flip angle. As the PD of various tissue obtained differs only by a few percent, this pulse sequence is not widely used. **Air contains** a low density of protons; therefore sinuses show no proton image. **Trabecular bone**, on the other hand, contains many protons but still generates no signal. This is because the protons are tightly bound and have a T2 decay time so small that the signals vanish before conventional MR imaging is able to detect them.

Relaxation times are affected by the chemical composition of the tissue being studied. Each normal tissue in the body has a specific relaxation time which is either shortened or prolonged by certain pathological changes.

The choice of a short TR enhances the T1 contrast between fats and liquids. On the T2 decay curve, each tissue starts at a different level. Fats are characterized by a short T2 and liquids by a long T2: there is a crossing point between the two curves where the two substances show an isointense signal.

Intensities of Normal Anatomical Structures

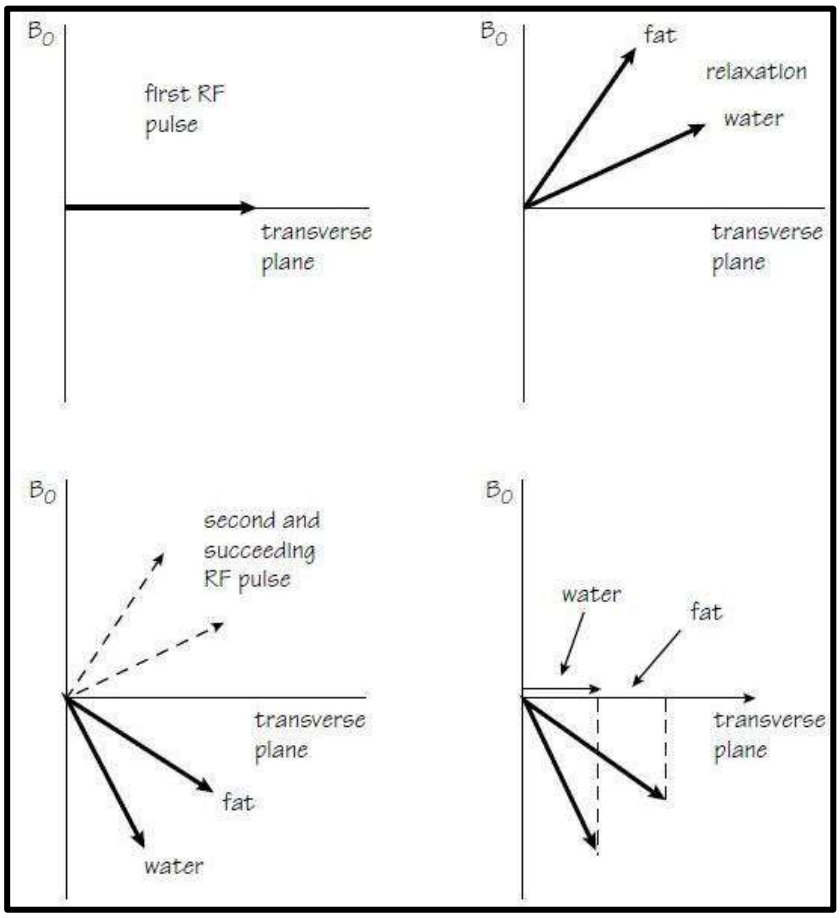
T1 weighting

In a T1 weighted image, differences in the T1 relaxation times of tissues must be demonstrated.

-To achieve (T1 weighted image):

- For T1 weighting differences between the T1 times of tissues is exaggerated and to achieve this the TR must be short.
- To remove T2 effects the TE must also be short

the **T1 recovery time** and is the time it takes for 63% of the longitudinal magnetization to recover in a tissue. The time during which T1 recovery occurs is the time between one RF excitation pulse and the next. **This is the repetition time (TR)**. The TR therefore determines how much T1 recovery occurs in a tissue.



Signal brightness could be seen in the T1:

- In T1 weighted images, tissues with short T1 relaxation times such as fat, are bright **(high signal)**, because they recover most of their longitudinal magnetization during the TR.
- Tissues with long T1 relaxation times such as water, are dark **(low signal)** because they do not recover much of their longitudinal magnetization. T1 weighted images best demonstrate anatomy but also show pathology if used after contrast enhancement (to identify solid from cystic lesion).

Table (1): Signal intensities seen in T1 weighted images

High signal	fat haemangioma intra-osseous lipoma radiation change degeneration fatty deposition methaemoglobin cysts with proteinaceous fluid paramagnetic contrast agents slow flowing blood
Low signal	cortical bone avascular necrosis infarction infection tumours sclerosis cysts calcification
No signal	air fast flowing blood tendons cortical bone scar tissue calcification

T2 weighting

In a T2 weighted image the differences in the T2 relaxation times of tissues must be demonstrated.

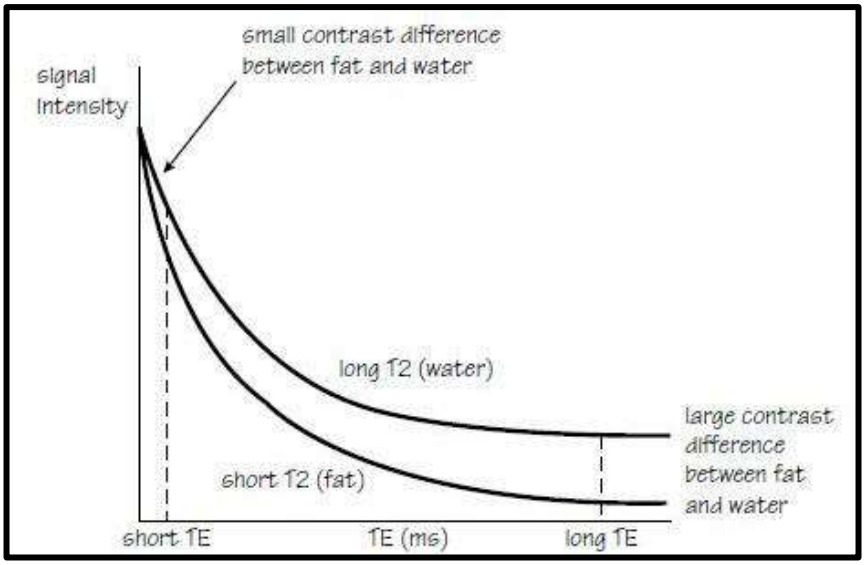
-To achieve (T2 weighted image):

1- For T2 weighting the differences between the T2 times of tissues is exaggerated, therefore the TE must be long.
2- T1 effects are diminished by selecting a long TR.

the **T2 decay time** and is the time it takes for 37% of the transverse magnetization to dephase (37% is left in phase) in a tissue. The time during which this occurs is the time between an RF excitation pulse and when signal is collected in the receiver coil. **The echo time (TE)** therefore determines how much T2 decay occurs in a tissue when signal is collected.

Signal brightness could be seen in the T2:

- Tissues with a short T2 decay time such as fat are dark **(low signal)** because they lose most of their coherent transverse magnetization during the TE period.
- Tissues with a long T2 decay time such as water are bright **(high signal)**, because they retain most of their transverse coherence during the TE period.
- T2 weighted images best demonstrate pathology as most pathology has an increased water content and is therefore bright on T2 weighted images.



Typical parameters T2 W images

TR 2000 ms , TE 70 ms

Table (2): Signal intensities seen in T2 weighted images

High signal	CSF synovial fluid haemangioma infection inflammation oedema some tumours haemorrhage slow-flowing blood cysts
Low signal	cortical bone bone islands de-oxyhaemoglobin haemosiderin calcification T2 paramagnetic agents
No signal	air fast flowing blood tendons cortical bone scar tissue calcification

Proton density (PD) weighting

In a PD weighted image differences in the proton densities (number of hydrogen protons in the tissue) must be demonstrated.

To achieve this:

- both T1 and T2 effects are diminished. T1 effects are reduced by selecting a long TR and T2 effects are diminished by selecting a short TE.

Signal brightness could be seen in the PD:

- Tissues with a high proton density are bright (high signal) because the high number of protons result in a large component of transverse magnetization.
- Cortical bone and air are always dark on MR images regardless of the weighting as they have a low proton density and therefore return little signal.
- Proton density weighted images show anatomy and some pathology.

Typical values

TR 2000ms+ TE 10–30ms

Fig. 6 Proton density contrast.

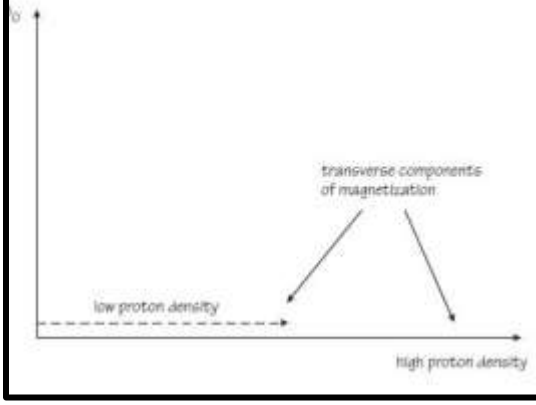
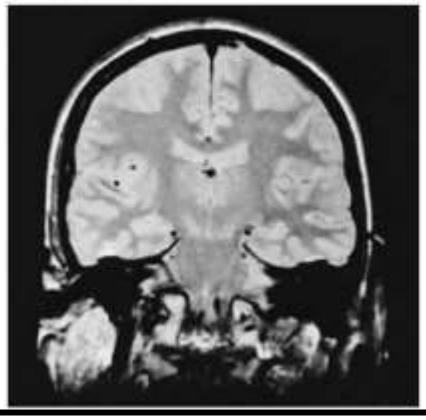


Fig.7 Coronal FSE PD weighted image of the brain.



Pathological Changes and Effects of Relaxation Times

Pathological processes alter the microenvironment of tissues, changing the balance of water and fat, and hence, their relaxation times:

T1 Changes

- **Increase in water content** (edema, tumor, inflammation): **Prolongs T1** → tissue appears darker on T1-weighted images.
- **Fatty degeneration, subacute blood: Shortens T1** → tissue appears brighter.

T2 Changes

- **Increase in free water** (edema, demyelination, necrosis): **Prolongs T2** → tissue appears brighter on T2-weighted images.
- **Dense cellularity (tumors), paramagnetic substances (hemosiderin): Shortens T2** → tissue appears darker.

Both the T1 and T2 recovery times can either be shortened or prolonged by the following table (3):

Table (3): T1 and T2 changes with different substance/pathology and imaging appearance

T1 Change	Substance/Pathology	Imaging Appearance	T2 Change	Substance/Pathology	Imaging Appearance
Shortened	– Lipid – Paramagnetic substance: a. Copper b. Iron c. Manganese – Mucus – Cholesterol – Postradiation changes (after two weeks) – Hemorrhage (methemoglobin) – Increased protein content – Melanin	Bright (high signal)	**Shortened**	– Air – Calcium – Cortical bone – Paramagnetic substances – Fat	Dark (low signal)
Prolonged	– Air – Calcium – Cortical bone – Edema – Demyelination – Neoplasia – Infection – Ischemia – Infarction – CSF	Dark (low signal)	**Prolonged**	– Demyelination – Infection – CSF – Ischemia – Neoplasia – Edema	Bright (high signal)