Al-Mustaqbal University
Biomedical Engineering Department

Class: 5th

Subject: Biomedical Instrumentation Design II

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1st term – Lect. 7: Diffusion, Perfusion, and Functional MRI

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MRI Design: Diffusion Weighted Imaging.

- Diffusion is a term used to describe moving molecules due to random thermal motion. It is also called ***Brownian motion***.
- This motion is restricted by boundaries such as ligaments, membranes and macromolecules and by pathology, and the parameter used to describe the rate of diffusion in tissues is called the diffusion coefficient.
- Practically, other sources of motion are present, like microcirculation.
- When strong gradients are applied this effect is minimal and so the term apparent diffusion coefficient or ***ADC*** is commonly used.
- Tissues in which diffusion is free have a high ADC, whereas those with restricted diffusion have a low ADC

MRI Design: Diffusion Weighted Imaging.

Table 25.1 Equations of DWI.

	ADC ($x10^{-3}mm^2/s$)	relative signal when b=1000
Cerebral spinal fluid	2.94	0.05
Grey matter	0.76	0.47
White matter	0.45	0.63

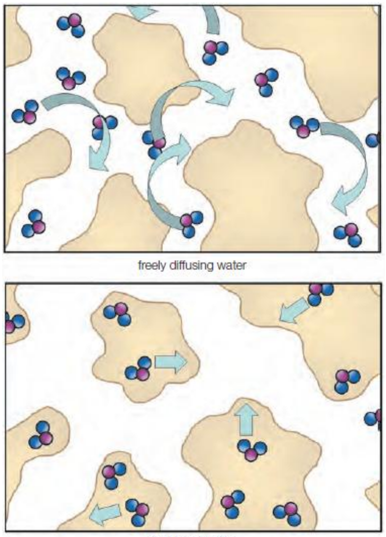

Figure 25.1 Free and restricted diffusion.

MRI Design: Diffusion Weighted Imaging.

- **Diffusion weighted images (DWI)** are acquired by sensitizing this motion with the use of strong gradients.
- Two equal gradients are usually applied on either side of a 180° RF in a spin echo type sequence (called a **Stejskal Tanner scheme**).
- The gradient pulses are designed to cancel each other out if spins do not move, while moving spins experience phase shift.

MRI Design: Diffusion Weighted Imaging.

- Signal attenuation, therefore, occurs in normal tissues with free random motion (high ADC), and high signal appears in tissues with restricted diffusion (low ADC).
- The amount of attenuation depends on the amplitude and the direction of the applied diffusion gradients and the ADC of the tissue.
- Diffusion gradients applied in the X, Y and Z axes are combined to produce a diffusion-weighted image (isotropic image).
- When the diffusion gradients are applied in only one direction, signal changes reflect the direction of axons (anisotropic image).

MRI Design: Diffusion Weighted Imaging.

- Diffusion gradients must be strong to achieve enough diffusion weighting.
- Diffusion sensitivity is controlled by a parameter ‘b’ that determines the diffusion attenuation by modification of the duration and amplitude of the diffusion gradient; ‘b’ is expressed in units of s/mm^2.
- Typical ‘b’ values range from 500 s/mm^2 to 1000 s/mm^2.

MRI Design: Diffusion Weighted Imaging.

- As ‘b’ increases, diffusion weighting also increases and vice versa.
- The ‘b’ value is an extrinsic contrast parameter that controls how contrast is derived in a diffusion weighted image, in that high ‘b’ values exaggerate the differences in a tissue’s ADC values (an intrinsic contrast parameter).

MRI Design: Diffusion Weighted Imaging.

Table 25.2 Typical ADC values.

Equations		
$b = \gamma^2 x G^2 x \delta^2 x (\Delta - \delta/3)$	b is the b value or b factor (s/mm^2) γ is the gyromagnetic ratio (MHz/T) G is the gradient amplitude (mT/m) δ is the gradient duration (ms) Δ is the time between two pulses (ms)	The b value or b factor is a function of the amplitude, duration and interval of the gradients in the Skejskal Tanner scheme.

MRI Design: Perfusion Imaging.

- Perfusion is a measure of the quality of vascular supply to a tissue.
- Since vascular supply and metabolism are usually related, perfusion can also be used to measure tissue activity.
- Perfusion imaging utilizes a bolus injection of gadolinium administered intravenously during ultrafast T2* acquisitions, thus causing a transient decreases in T2* in and around the microvasculature perfused with contrast.
- After data acquisition, a signal decay curve can be used to ascertain blood volume, transit time and measurement of perfusion.
- This curve is known as a time intensity curve.
- Time intensity curves for multiple images acquired during and after injection are combined to generate a cerebral blood volume (CBV) map.
- Mean transit times (MTT) of contrast through an organ or tissue can also be calculated.

MRI Design: Functional MRI.

- This is a rapid MR imaging technique that acquires images of the brain during activity or stimulus and at rest.
- The two sets of images are then subtracted, demonstrating functional brain activity as the result of increased blood flow to the activated cortex.

<u>BOLD imaging</u>

- The most important physiological effect that produces MR signal intensity changes between stimulus and rest is called **blood oxygenation level-dependent** or **BOLD**.

MRI Design: Functional MRI.

- BOLD exploits differences in the magnetic susceptibility of oxyhaemoglobin and deoxyhaemoglobin.
- **Haemoglobin** is a molecule that contains iron and transports oxygen in the vascular system, as oxygen binds directly to iron.
- **Oxyhaemoglobin** is a diamagnetic molecule in which the magnetic properties of iron are largely suppressed.
- **Deoxyhaemoglobin** is a paramagnetic molecule that creates an inhomogeneous magnetic field in its immediate vicinity that increases T2*.